PREFACE

Chronology is closely connected with history and archæology The great importance of archæo logical research has been acknowledged by most of the advanced nations The Indian Government has created a special department of Archæology for the discovery and preservation of the ancient relics of Indian arts and architecture From the ruins of ancient cities now lying buried under ground old inscriptions tablets coins copper plates vases monu ments etc are being unearthed every year and the work of comparing and verifying their dates so as o fix their chronological place has vastly increased

Books on Indian Chronology written and publish d under Government patronage by scholars like Messrs Warren Sewell and Pillai are at present available But it may be said of them without dis paragement that they are much above the reach and omprehension of the class of average students An elementary book written on the lines of Science Pri mers explaining with clearness the first principles of chronology and gradually leading the reader to a

thorough understanding of the mathematical and astronomical theory of chronology is, we believe, a desideratum, and the present book is written with the object of removing it

The first three chapters are devoted to the explanation of Eras, the natural units of time and the importance of personal observation of stars and of the movements of the Sun and Moon among them. Chapter IV is intended to illustrate and fix the ideas about the five chief parts of the Hindu Panchānga Chapter V explains the cause and the effects of the variable motions of the Sun and Moon on their ending times Chapter VI proves conclusively the astonishing identity of the ancient and modern inequalities of the Sun and Moon Chapters VII and VIII contain the definitions of the technical terms and the theory of the Adhika and Kshaya months

The calculation of the Luni-Solar Calendar begins with Chapter IX The next four chapters treat of the calculation of the Solar, Musalman, and Christian Calendars and of the Samvats of Northern India Chapter XIV contains brief sketches of the Vedic the Chinese, the Jewish and Ecclesiastical Calendars Chapter XV and XVI treat of the Lunar and Solar Eclipses and of the various kinds of Time Chapter XVII is intended for advanced readers and contains miscellaneous notes relating to theory, comment, and antiquarian research The last Chapter XVIII is devoted to Bibliography and is followed by tables and a full Index

It now remains to thank friends and well-wishers for their advice and help. My most hearty thanks are due to Prof. R. Zimmermann of St. Xavier's College, Bombay; and to Mr. P. V. Kane, M.A., High Court Pleader, Bombay, for valuable suggestions which have considerably added to the utility of this book; and also to Mr. D. V. Apte, B.A., of Hangandi for information regarding the intricate system of Chronology adopted in the official correspondence during the Maratha Period

It is impossible for me to express fully my thankfulness to the Bombay Branch of the Royal Asiatic Society which has, no doubt, done important service to Archæology by undertaking to print and publish this book of mine, the like of which has, so far as I know, never before appeared in print in this Presidency.

BELGAUM,
11th October 1921

V. B. KETKAR,
Author.

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INDIAN AND FOREIGN CHRONOLOGY

LUNI SOLAR, SOLAR AND LUNAR

(B C 3102 to A D 2100)

CHAPTER I

INTRODUCTORY

THE ERAS TABLE 1

CHRONOLOGY is the science of ascertaining the exact moment of the time in days months and years of a particular Era when any past event actually took place It is, therefore closely connected with History and Astronomy Time may be compared to an imaginary straight line, or to a high way of which we can see neither the beginning nor the end It is, therefore, absolutely necessary to agree upon an initial moment or *Epoch* as it is called to measure time from The time so measured has reference to the particular Era which begins at that Epoch The Era is supposed to extend both in the past and the future without limit Chronology treats therefore of the different Eras started by different nations at different Epochs It furnishes the means with which one can fix or verify the dates of events mentioned in historical records with reference to particular Eras and can establish concordance among them

2. Table 1 gives the details of about 25 *Eras* But all of them are not in use at present Most of them have shared the fate of the nations that started them Those Eras alone that have been thought fit to serve as basis of Astronomical Civil and Ecclesiastical calculation have survived The Eras used at present in India in civil and religious transactions are (i) The Kali Yuga or the Yudhisthira Era (ii) The Vikrama Era (iii) The Shaka Era and (iv) the Christian Era This last Era which

is the era of the present rulers of India and which is used throughout the civilized world has been chosen in Table I and elsewhere to serve as a thread of a string of beads connecting all the other Eras

3 The years are the chief constituents of the Eras But they differ from each other in respect of their sub divisions or months This difference introduces into Chronology the three systems of Calendars called the Luni-solar the Solar and the Lunar The Shaka the Christian and the Mahomedan Eras follow respectively the above three systems

4 The years differ in other respects also such as the mode of enumeration their length and beginning In some Eras the years denote the number of years completed or elapsed as in the Shaka and Kali yuga Eras In others as in the A D or Christian Era they denote the *current* year Again the years of the same system of Calendar begin with different months in different parts of India The reader will do well to understand thoroughly the several details about each of the Eras given in Table I, and also to bear in mind their points of agreement and difference

5 Mutual conversion of the years of different Eras —By conversion is here meant the calculation of years of different Eras which begin in the same year of the Christian Era

There are three chief scales of numbering the years in Chronology They are—

(1) The Mathematical scale of expired years—

$$-4 \; -3 \; -2 \; -1 \; E + 0 \; + 1 \; + 2 \; + 3$$

(2) The Mathematical scale of current years—

$$-3 \; -2 \; -1 \; -0 \; E + 1 \; + 2 \; + 3 \; + 4$$

(3) The Historical scale of mixed years—

$$\text{B C} \; -4 \; -3 \; -2 \; -1 \; \Gamma + 1 \; + 2 \; + 3 \; + 4 \; \text{A D}$$

The letter Γ indicates the year with which any Era adopting the scale, begins In column 2 of Table I, is noted the scale which each Era follows —Scales (1) and (2) are homogeneous but in Scale (3) the B C years are expired and A D years are current

On comparing the Scales (1) and (3) with (2) it is seen that—

(a) The expired years can be changed into current ones by simply adding to the former + 1 and for the converse by adding — 1

(b) The historical years are changed into current ones of scale (2) by adding + 1 to the B C years only, leaving the A D years untouched and for the converse by adding — 1 to the minus years of Scale (2)

The formula for the mutual conversion of years of different Eras is—

$$A + B - C = X$$

Where A is the given year of a given Era B is the Christian year in which the given Era begins as shown in col 2 of Table 1 C is the Christian year in which the required Era begins (col 2 Table 1) Then X will be the current year of the required Era

Before solving for X the given years A and the beginning years B and C must be changed into current years of Scale (2) by means of the above Rules (a) and (b) And after solution the current year X should be reduced, if necessary to its original Scale of expired years by adding — 1

Examples —Required (1) the Kali yuga (2) the Shaka (3) the Jewish and (4) the Julian period years corresponding to 1920 A D (5) the Kali yuga year corresponding to 45 B C (6) the Shaka and (7) Newar years corresponding to Kaliyuga 5000 and (8) the Christian year corresponding to Kaliyuga 3000

	A	$B - C$	X				
(1)	1920 +	1 + 3101 —	5022	cur or	5021	exp	Kali
(2)	1920 +	1 — 78 —	1843	do	1842	do	Shaka
(3)	1920 +	1 + 3760 =	5681	do	Jewish		Era
(4)	1920 +	1 + 4712 —	6633	do	Julian		Period
(5)	— 44 +	1 + 3101 —	3058	do	3057	do	Kali
(6)	5001 —	3101 — 78 =	1822	do	1821	do	Shaka
(7)	*5001* —	*3101 — 879* —	*1021*	do	*1020*	do	Newar
(8)	3001 —	3101 — 1 =	—101	do	102	do	B C

Table 38 presents the view of the mighty river Time whose tributaries the Eras flow together without mixing and sweep before them all mortal things

CHAPTER II

ON THE NATURAL UNITS OF TIME AND THEIR USE

6 It appears that men derived their first ideas of time from observation of the most vivid and striking natural phenomena and that the interval between any two consecutive phenomena gave them the idea about the units of time Sunrise is the most striking of all the natural phenomena and consequently, the interval between two consecutive sunrises came to be considered as the most important unit of time This the smallest of the natural units is called *Day* It is noteworthy that it also coincides with the cycle of bodily functions of animals such as work sleep digestion etc

7 The next phenomenon that struck men in their nomadic life must have been the *Lunar phases* They could easily watch from their huts the varying phases waxing from being a slender crescent till the Moon appeared round and full and then waning till she was reduced to a faint crescent and finally lost sight of in the rays of the Sun to appear again as a crescent on the Western horizon This natural unit of time is called *Lunar month* It consists of about $29\frac{1}{2}$ days and its duration is long enough to suit the ordinary business of human life

8 When hunting was found inadequate as a means of livelihood men must have been forced to betake themselves to agriculture This change naturally drew their attention to the phenomena of *Seasons* They observed that the Sun rose on the Eastern horizon at a particular point at the commencement or about the beginning of a particular season After a long and patient course of observation they might have perceived that the cycle of the seasons exactly coincided with the cycle of the Solstices This was a great discovery in that primitive state of

humanity. The cycle of seasons or the *year*, which consists of about 365 days, was the longest of the three natural units of time. The course of sacrifices, which was kept up by the Rishis and priests, throughout the year, seems to have been originally intended as a means of ascertaining the advance of seasons, so essential to agriculture. The Vedic hymns very aptly say that the seasons dwell in the year.

9. The knowledge of Astronomy among all the ancient nations of the world, such as the inhabitants of Egypt, Assyria, India and China, seems to be limited to the ascertaining of the lengths of these three natural units. The Vedic Calendar as we know it at present, from the Vedânga Jyotisha, is based on these three units only. The Eras were then unknown, or if they existed at all, they were the regnal eras, *i e*, they began and ended with the reigns of each king. In the Hindu Puranas, Chronology is often based on the lists of kings, but very rarely on the lengths of their reigns.

CHAPTER III

OBSERVATION OF THE MOVEMENTS OF THE SUN AND THE MOON AMONG THE STARS

10. **Importance of Personal Observations**.—To solve mechanically, the problems of Chronology by means of rules and tables, without understanding their theory, does not, in our opinion afford real pleasure. We therefore intend to render help in this direction, to any student, if he is only willing to bestir himself a little to acquire knowledge by personal efforts and experience. For this purpose, he should first select a place, from which he can see the whole of the circular horizon, unhindered by buildings, trees or hills, and commence his observations at dusk. He will then see that the stars are slowly and continually moving from east to west, that new stars are rising in the east and the old ones are setting in the west during the whole night. If he continues these observations for a few days, he will be convinced of the diurnal motion of the stars, the Moon, and the planets. But in the case of the Moon, he will notice this peculiarity, that in

addition to her motion westwards along with the stars she also moves eastward slowly among them If he observes her positions relatively to stars for a month he will find that she has made one complete revolution in about 27⅓ days and has returned to the star from which she had set out The Stars Regulus (Magha) Spica (Chitrâ) or Antares (Jyestha) may conveniently be used as starting points in making this experiment (Fig 1)

11. The Sun also moves like the Moon among the stars from west to east and completes one revolution in about 365¼ days But as the Sun and the stars cannot be seen side by side like the Moon owing to his overpowering lustre it is not easy to determine the exact period of his revolution among the stars without the aid of instruments A rough estimate of it can be obtained by observing the mean duration of the *heliacal* risings and settings of one of the bright stars like Canopus or Agastya which phenomena are given in a Panchanga every year

12 The Sun s motion can only be inferred The Moon appears to rise or set on the horizon of a place almost diametrically opposite to the Sun on the Full Moon day This cannot happen unless both the luminaries travel nearly along the same route over the sky The route is called the *Zodiac* and the great circle which runs along the middle of it is called the *Ecliptic* or the place where the eclipses happen The observer s work will be much facilitated if he makes use of a star atlas* in his observations

13 The Earth considered as Motionless —The ancient astronomers with the exception of the Indian Astronomer Arya-bhatta believed that the Earth remained fixed† in the centre of the Universe and that the Moon and the Sun revolved round her in 27⅓ and 365¼ days respectively This belief continued to prevail till about the year 1500 A D when *Copernicus* declared that the Earth rotated round its axis and at the same time revolved round the Sun with the Moon revolving round her We shall

* The author's Marathi Nakshatra Vijnâna contains 5 celestial maps and much useful information about the stars

† Compare the words Latin terra and Sanskrit Sthira meaning the Earth the terra firma.

however stick to the old belief, in explaining the ideas about the tithis, and nakshatras, as the appearances from the earth s surface easily lead to it Their explanation we shall attempt in the next chapter

14. The reader will have noticed that the chief drawback in the natural units of time is their *incommensurability* with each other (see Table 37, Days and Months) Not one of them is an exact multiple or a sub multiple of any other Men were therefore required to keep the account of time in these three units separately The annual register, in which this account is kept, is called a *Calendar* or a *Panchânga* The *Calendars* are called Lunar, Solar, and Luni Solar, according to the importance given to one or the other or both of these units

15. The Zodiacal section of the starry vault (Fig 1) over the head of a person on the equator may be considered as the dial of a vast clock, over which the Sun and Moon revolve like the hour and minute hands In the *Lunar Calendar*, the time is measured by the number of conjunctions of the Sun and the Moon hands on this dial, and 12 of these conjunctions, or *lunations* as they are called, are supposed to make one year In the *Solar Calendar*, the existence of the Moon-hand is wholly ignored, and the years are reckoned by the number of revolutions of the Sun-hand alone with reference to a fixed point or a star such as the Star Spica The year is sub divided into 12 months each containing a certain number of days fixed arbitrarily or upon some principle

16. The *Luni Solar* Calendar is a complex thing and is rather difficult to comprehend In it the months are lunar, and the years are solar The inconvenience caused by the incommensurability is remedied, however, by means of the intercalary months, which are peculiar to the Luni Solar Calendar The *tithis* mark the position of the Moon in relation to that of the Sun, while the *nakshatras* denote her position in relation to a fixed starting-point The Yogas are simply the sum of the distances of the Sun and the Moon from the starting point, and as such they do not indicate any natural phenomenon

CHAPTER IV

THE SKY-DIAL AND THE CLOCK-DIAL COMPARED

(Figure 1)

17. In the preceding chapters we have described how the Sun and the Moon appear to revolve continually along the same path among the stars, and how the periods of their revolutions were utilized by the ancient people to measure their time, which is the chief object of Chronology.

But with our eye placed on the surface of the earth, it is impossible to see the whole of their path at one view and consequently the description fails to be as clear and impressive as it ought to be. We shall therefore, change our stand-point and describe their motions as they would appear to us from a most distant point perpendicular to the plane of their orbits.

18. View from an Imaginary Stand-point.—When seen from the surface of the Earth, only half the Ecliptic is visible above the horizon at any instant, and the other half is hidden under it. In order to bring the whole of the Sun's orbit in our view, we must recede far away from the Earth, and place ourselves in empty space. We know from daily experience, that objects begin to look smaller as we recede from them. We may, therefore, imagine to have travelled millions and millions of miles towards the *southern side* of the Ecliptic to a place whence the entire orbit of the Sun may look as small as the dial of a clock, and the Earth a mere point at its centre. We may also imagine for the sake of analogy that the Sun and the Moon revolve in the same circle with their own angular motions and that they are connected with the common centre *E* of their orbits with bars so as to present, in accordance with the Siddhantic or Ptolemaic system, the appearance of the hour and minute hands respectively. As we now no longer partake of the Earth's diurnal rotatory motion, we may imagine that we see the Sun's orbit, *i.e.*, the ecliptic, with the stars set on its rim, quite at rest, as shown in Fig. 1 and the Earth's southern hemisphere rotating clock-wise in 24 hours. Although a point, the Earth is here magnified so

as to show Africa, Australia and South America, India being out of view

19. View of the Ecliptic superposed by a Clock Dial.— Next suppose that the Ecliptic is superposed by a clock dial, so that the 12 o'clock point coincides with the zero starting point of Ashvini and the 6 o'clock point coincides with the brilliant Star Spica when seen from E, the Earth's centre In this position the hour divisions of the dial will coincide with the 12 equal divisions or *Râshis* of the Ecliptic, and each minute-space on the dial will contain six degrees of longitude on the Ecliptic Consider another circle, concentric with the dial, to be drawn outside the dial and to be divided into 27 equal parts from the same zero starting point of Ashvini, representing the 27 nakshatra spaces Also imagine that a smaller moveable card board circle *ABC* has its diameter *KEA* firmly attached to the Sun-hand *EAS* by two clamps, so that it is always carried by the Sun hand along with it like the *alarm wheel* in a clock. Suppose the circumference of this smaller moveable circle to be divided into 30 equal parts, representing the tithis, beginning from the point *A*

20. Illustration.—Figure 1 will present a lucid and impressive picture of the daily movements of the Sun and the Moon in the sky, affording correct and vivid ideas of the tithi, the nakshatra, and the yôga, as understood in a Luni Solar Calendar From analogy we shall now call the hour and minute hands (*ES*, *EM*) on the dial, the Sun and Moon hands respectively Now suppose that the Sun and the Moon hands occupy in the sky the positions of the hour and minute hands respectively, when the time by the clock is 36 minutes past four o clock In this position the *Sun hand* will be at the 23rd minute space, and consequently its longitude from the origin *O* of Ashvini will be equal to $23 \times 6° = 138$ degrees on the dial The Sun hand shall have also brought with it the ending point *A* of the 30th tithi or Amâvâsya, pointing to 138° degrees Similarly, the *Moon hand* being at the end of the 36th minute-space its longitude from the origin *O* will be $36 \times 6 = 216$ degrees, which are marked along the edge of the Zodiac

21. The Tithi.—The angular distance *SEM* of the Moon from the Sun is called the *Elongation* of which 12 degrees make one tithi. In the present instance $216^\circ - 138^\circ = 78^\circ$ is the Elongation. This divided by 12 gives the number of *tithis* elapsed to be 6½. Also the Moon hand *FM* supports this calculation by crossing the tithi-circle exactly in the middle of the 7th tithi.

22. The Nakshatra.—The longitude of the Moon is 216°. This divided by 13⅓° (the length of a Nakshatra space) gives 16.2 as quotient. This means that the Moon hand has travelled over 16 nakshatras and has finished a fifth part of the 17th nakshatra which is called *Anuradha* (See Appendix.) The Moon appears to occupy this very position on the circumference of the outer circle in Fig. 1. The nakshatra occupied by the Sun is for distinction called the Mahanakshatra.

23. The Yoga.—The nakshatra of the Sun hand is here similarly found out by dividing the Sun's longitude 138° by 13⅓. The quotient is 10.35 which indicates that the Sun is moving in the 11th nakshatra called *Purva Phalguni*. This is borne out by its position in Fig. 1 where it will be seen to have crossed a third of the 11th nakshatra. The sum of the nakshatras of the Moon and the Sun is called a *Yoga* which literally means a Sum. It is merely a numerical expression and does not indicate any phenomenon. In this instance the Yoga is $16.20 + 10.35 = 26.55$ i.e. the 27th Yoga *Vaidhriti* is current.

24. The Mahapata.—When the sum of the tropical longitudes of the Sun and the Moon (i.e. longitudes measured from the vernal Equinox) amount to 180° or 360° there is the possibility of the most dreaded and inauspicious time called *mahāpāta* which is to be shunned by pious Hindus in religious ceremonies. In the former case it is called *Vyatipata* and in the latter case *Vaidhriti*. In the Vyatipata the two luminaries when possible attain equal declinations on the *same* side of the celestial equator while in the Vaidhriti they possibly do the same but on the *opposite* sides of it.

Note.—The problem of finding the exact moment when the centres of the luminaries attain the same declination was considered in ancient times (i.e. when spherical trigonometry was unknown) as the most crucial test of an astronomer's proficiency.

25. Karanas.—The halves of tithis are called *karanas*, so that there are 60 karanas, in a lunar month They resemble the half hourly strokes in a clock.

26. The Solar and the Luni Solar months and dates.—The sun-hand in its annual course beginning with the zero point of Ashvini marks the Solar month and date on the dial In Figure 1 it is in the sign Simha and has finished three-fifths of it The Solar date is, therefore, approximately the $\frac{30\times3}{5}$ = 18th of *Simha* or *Chingam* of Malâbâr (Table 15)

As the Moon hand *EM* walks 13 times faster it overtakes the Sun hand in each of her monthly revolutions The instant when the two hands are seen one over the other, is the ending moment of Amâvâsyà (Sanskrita — Amâ = together and Vasa = to dwell), or conjunction It is also the last moment of the preceding Lunar month and the beginning of the next In the present case (Fig 1) the Moon hand indicates the 7th tithi, and the Sun hand the 18th solar date So twelve days after, the Sun hand will enter the sign of Kanyà, and the Kanyâ Sankrânti will therefore occur on the 7 + 12 = 19th *tithi* or *Vadi-chaturthi* Hence the current lunar month is *Bhâdrapada* (*vide* secs 66 and 70) and the tithi is *Shukla Saptami*

The Pakshas—After the Amâvâsyâ or conjunction, the phases of the Moon go on increasing till she comes to *K*, which point is moving with the Sun diametrically opposite to it There she appears full and round, and the aspect is called Purnimâ or Full Moon The period from Amavâsya to Pûrnima is called *Shukla-paksha* or bright fortnight and that from Pûrnimâ to Amâvâsyâ is called *Krishna paksha* or dark fortnight

27. The perpetual Clock—By practice one is enabled to state the number of the current tithi by a mere glance at the Moon's orb The chief bright star in the nakshatra, which rises at about sunset opposite to the Sun, tells approximately the name of the Lunar month It also shows the progress of the night by its altitude at any moment Thus the ancient Hindus had turned the starry vault into a big eternal clock It required no winding nor was the motion of the hands affected by atmospheric changes It was a real *Swayam vaha*, *i e*, keyless Kalayantra

28 The points of difference between the artificial and Heavenly Clocks —We will now notice the points of difference In the former the motions of the hands are uniform and commensurate *i e* they are related by simple ratios In consequence of this interdependence the configurations of the tithis nakshatras and yogas recur not only at fixed intervals but at fixed points on the dial But these two essential properties being absent in the motions of the Sun and the Moon the conjunctions oppositions and quadratures do take place at any time and at any point of the dial of the celestial clock It often happens that at the moment when the Sun hand reaches the zero point of Ashvini at the end of the Solar year the Moon hand is seen anywhere on the celestial dial For instance (see Table 3) in the Kali year 0 the Sun arrived at the zero of Ashvini on the Celestial Clock Dial on 3 579 (Tuesday 34gh 44 pa) when the tithi was 27 795 *i e* the Moon was on (27 795 × 2) = 55 6 minute spaces distant from the Sun

The absence of interdependence is therefore the reason why it is necessary to compute separately the positions of the Sun and the Moon on the heavenly dial and thence to calculate the moments of the completion of the tithis nakshatras and yogas and to publish them in a panchanga in advance for the observance of the religious rites and the performance of civil transactions

The nature and cause of the variable motions will be explained in the next chapter and the method of computation of the Luni Solar Calendar will be describ d in Cl apter IX

CHAPTER V

MEAN AND TRUE POSITIONS

The variable Daily Motions of the Moon and the Sun (Fig 2)

29 The ancient astronomers believed that the Sun the Moon and the planets revolved with uniform motion in perfectly circular orbits and that although the Earth s centre was the centre of the Ecliptic or Zodiac yet the centres of their orbits were placed not in the Earth s centre but at some distance from it That owing

If Cf be the direction of the Moon f with respect to the line CA, pointing to a star at infinite distance, when seen from C at a certain moment, then Ef or its parallel Gr will be her direction with respect to the same star-line CA, if seen from E, the Earth's centre

32. It is manifest then that in the first half of her mean anomaly from 0 to 180 degrees, she (r) always appears behind her mean position f, and is always ahead of it in the second half, *i e*, from 180 to 360 degrees (*Vide* Table 32) Also although the motion round the centre C is always uniform *viz*, 791′ she will appear to move with continually accelerated motion and enlarging disc in the first half of her anomaly, owing to the continuous decrease in her distance fE from the Earth E Similarly her motion will appear continually retarded in the second half owing to the increase in her distance fE every moment the minimum and maximum being 722′ and 859 (*Vide* Table 25)*

Considering the conditions of the problem it is obvious that the Equation of the Centre must reach its maximum (302) where Ef is perpendicular to AP But in Table 32 we find the maximum given when Cf is perpendicular to AP *i e* when the mean anomaly is 90 or 270 degrees This is no doubt wrong The error may be traced to the infancy of Astronomy when it was guessed for the first time that the equation or inequality increased with the sine of the anomaly and not in arithmetical progression as was supposed in the time of the Pitâmaha S The correct calculation required the knowledge of Trigonometry which being then unknown the primitive astronomers were content with the Tables 31 and 32 of the equation calculated with the sine of anomaly only and called it sine-correction ज्याफल Bhâskarâchârya alludes to this defect but is unable to explain it He simply calls it a strange theory and asks his pupils not to raise the question why the annual parallax is not similarly computed with the sine of the commutation angle

नाक्रमस्य न कर्म ज्यिवद्यतो विचित्रा फलवासनात्र

दृग्गतिवासना ॥ १० ॥

What is said above in respect of the Moon's movement applies wholly to the Sun's movement also

* Note —The ancients explained all the inequalities by means of epicycles and eccentrics on the hypothesis of circular orbits and uniform motion So we have done the same here For all the theory see author's Marathi [illegible]

33. Effects of the Equations of the Centres of the Moon and the Sun, on the ending moments of tithis, nakshatras and yogas.—It is easy to see that when the Moon is behind her mean place she will be late in arriving at the required distance to make up the required tithi nakshatra and yoga Therefore the correction to the mean ending moment due to the equation of the Moon's centre, must be plus or additive in the first half of her anomaly See Tables 7, 8 and 10 Similarly, owing to the advance of the Moon beyond her mean position during the next half she arrives sooner at the required distance, and the correction must, therefore be minus or subtractive so far as the Moon is concerned

34 The lagging of the Sun behind its mean position increases the elongation and his advance diminishes it So that a given tithi takes place earlier and the correction must therefore be minus in the first half of his anomaly and plus in the next half, so far as the Sun is concerned See Table 6

The effect of the Sun's equation of centre on the ending moment of a yoga, is similar to that of the Moon on the ending moment of a tithi See Table 9 (*Plus* in the first half and *minus* in the second half of the Sun's anomaly.)

The Sun can produce no effect on the ending moment of a nakshatra which depends entirely on the Moon's equation of the centre

35 The suppression * and repetition or Vriddhi of tithis etc., how caused —The equations of the centres of the Sun and the Moon by causing variations of the ending moments of the tithis nakshatras and yogas, also shorten and lengthen their durations The duration of a tithi varies between 54 0 gh and 65 3 gh that of a nakshatra between 54 0 gh and 66 3 gh and that of a yoga between 52 2 gh and 61 5 gh When the duration of a tithi exceeds 60 gh it sometimes happens that the tithi begins shortly before the Sunrise on one day continues during the 60 ghs

* Of course kshaya tithis would occur even if the motions of the Sun and Moon were uniform as a mean tithi of 59 gh is smaller than a natural day of 60 gh but in that case they would occur at uniform intervals as in the Vedic calendar and there would be no tithi vriddhi The inequalities in the motions render the intervals between kshaya tithis irregular and make tithi vriddhi possible

of it, and ends shortly after the Sunrise of the following day. As the tithi on which the Sun rises is supposed to rule over that day the same tithi is shown on the two consecutive days in the Panchanga. This is called *The tithi Vriddhi* or the *Trisparsha* tithi. On the contrary, when the duration is less than 60 gh., it occasionally occurs that a tithi begins shortly after the Sunrise of a day and ends shortly before the next Sunrise. In this case the tithi touches neither the preceding nor the following Sunrise and is looked upon as a *kshaya tithi* or expunged tithi, and is not shown in the Panchanga. The Vriddhi and kshaya of nakshatras and yogas occur under similar conditions. The yoga is more liable to be suppressed than repeated.

36 The difference between the mean and true motions of the Moon is greatest at A and P and nil at B and D, i.e. it varies as the cosine of the anomaly. The equation of the centre, which is the integral or the total sum of all the differences of motion varies therefore as the sine of the anomaly according to the principle of Calculus. (*Vide* Sec. 38.)

CHAPTER VI

THE IDENTITY OF THE ANCIENT AND MODERN INEQUALITIES OF THE SUN AND THE MOON

37 The ancient Assyrian astronomers were undoubtedly the most intelligent and keen sighted people. The absence of accurate instruments for measuring time and angles in those ages probably compelled them to limit their observations to eclipses only. It is really wonderful that under such difficulties they should have succeeded so nicely in their determination of the solar and lunar inequalities. Their co-efficients are of course the aggregate of the co-efficients of the modern inequalities as they appear on the occasion of the eclipses.

38 We shall now demonstrate how the chief modern inequalities of the Moon and the Sun can be combined into two groups, one depending on the solar and the other on the lunar anomaly.

The following are the principal inequalities adopted by Prof P Hansen in his lunar and solar theories —

The inequalities of the Moon

Equation of centre	— 377 4 sin (☾ s anomaly)
Evection	— 74 4 sin (☾ — ☉) — ☾ s anomaly
Variation	+ 39 7 sin 2 (☾ — ☉)
Annual Variation	+ 11 9 sin ☉ s anomaly
Parallactic Equation	— 2 6 sin 2 (☾ — ☉)—☉ s anomaly

The inequality of the Sun

Equation of centre — 115 3 sin ☉ s anomaly

39 At the time of the eclipses the terms of the form 2 (☾ — ☉) in the above arguments become zero Consequently the third lunar inequality called variation vanishes altogether The fourth and the fifth inequalities can be grouped with the Sun s inequality with their signs changed in order that they may not adversely affect the time of the eclipses by the transfer

The fifth inequality twice undergoes the change of sign first owing to its transfer and secondly owing to the sign (—) minus attached to the Sun s anomaly in it and therefore remains unchanged

Consequently on the occasion of an eclipse the following two groups can be formed out of the six inequalities

The Lunar Group

{ — 377 4 sin ☾ s anomaly
{ + 74 4 sin ☾ s anomaly

The Solar group

{ — 115 3 sin ☉ s anomaly
{ — 11 9 sin ☉ s anomaly
{ — 2 6 sin ☉ s anomaly

40 By summing up these groups separately we obtain the following two single inequalities representing in value all the chief modern inequalities

☾ s equation — — 303 0 sin ☾ s anomaly
☉ s equation — — 129 8 sin ☉ s anomaly

— 432 8

These are identical with the following two inequalities, determined from observation by the Assyrians twenty five centuries ago (See Table 37 under Surya Siddhanta)

$$☾\text{'s equation} = -302'4 \sin ☾\text{'s anomaly}$$
$$☉\text{'s equation} = -130'5 \sin ☉\text{'s anomaly}$$
$$\overline{-432'9}$$

Note—The author of this work believes that the above demonstration is entirely his own and that he has not been anticipated before

CHAPTER VII

DEFINITIONS OF TECHNICAL TERMS

(Figure 3

The information and explanation given in the foregoing chapters may have it is hoped prepared the student's mind to understand the definitions of the following terms which are *technical* Many of them will appear mere recapitulations of what has been explained before

TERMS SIGNIFYING SPACE

41 The Siddhantic or Ptolemaic System Ancient astronomers supposed that the Earth lay at rest in the centre of the Universe and that the planets moved round it in circles in the following order viz the Moon Mercury Venus the Sun Mars, Jupiter and Saturn The sphere of the fixed stars moved far beyond the orbit of Saturn Their motion was uniform and was due to a great whirlwind called Pravahanila

42 The apparent circular path of the Sun among the stars is called the *Ecliptic* (Fig 1 or 3) It is supposed to be divided into 360 degrees each degree being subdivided into 60 minutes and each minute being again subdivided into 60 seconds The Moon and the planets always appear to move near it

43 The initial point on the Ecliptic from which the circular distances or longitudes of the Sun, the Moon and the stars are measured is called the *first point of Ashvini* or [illegible] It is situated according to the old Surya Siddhanta quoted in the

Pancha Siddhântikâ, diametrically opposite to the bright star Chitra (Spica, Fig 1) But owing to an excess of about 3 minutes in the period of the sidereal year adopted in all the Siddhantas this 1st point shifts itself forward, at the slow rate of about one degree in 420 years [*Vide* sec 200 (*a*) and sec 152 (*c*)]

44 The 12 equal parts into which the Ecliptic is divided, beginning at the first point of Ashvini are called *Râshis* or signs. The entry of the Sun into a Rashi is called his *Sankramana* or *Sankranti* (Fig 1), which is often used as a synonym for Râshi

45 The 27 equal parts into which the Ecliptic is divided, beginning from the first point of Ashvini, are called the *Nakshatras* Generally, the most conspicuous star found in the space of each Nakshatra is called its *Yôga tarâ* (Fig 1)

46 The distance of a heavenly body, measured eastward from the first point of Ashvini to the foot of the perpendicular dropped from the body upon the ecliptic is called its *longitude*, and the perpendicular is called its *latitude* (Fig 3) *Pn* is the Moon's longitude and *nm* her latitude

47 The angular distance of the centre of the Moon from the centre of the Sun is called her *elongation* Twelve degrees of elongation make one *tithi space* so that there are 30 tithi spaces in the circle of elongation, which is denoted by the symbol (☾ — ☉). (See Figs 1 and 3)

48 The linear distance from the centre of the Earth to the centre of the orbit of the Moon, or to the centre of the supposed orbit of the Sun is called the *eccentricity* It produces the equation of the centre (See the line *EC* in Fig 2)

49 The point on the circumference of the Moon's orbit, which is farthest from the Earth, is called the *Apogee* and the nearest point is called the *Perigee* (Fig 2)

50 The angular distance of the Moon or the Sun from their respective Apogees, as seen from the centre of their circular orbits, is called the *mean anomaly* for instance, the angles *ACf* in Fig 2 But as seen from the Earth's centre *E*, it is called the *eccentric* or *true* anomaly as the angles *AFf*

51 *The equation of the centre* is the angular distance, by which the Sun or the Moon moving uniformly in the eccentric orbit, is seen behind or ahead of the mean position It vanishes at Apogee and Perigee and attains its greatest value nearly half way between those two points See the angles *EfC* or the arcs *fr* (Fig 2)

52 *The Celestial Equator* is a great circle equidistant from the two poles It cuts the ecliptic in two opposite points called the *equinoxes* The point through which the Ecliptic passes to the northern side of the equator is called the *Vernal Equinox* and the other point is called the *Autumnal Equinox* (Fig 3) The equinoxes have a slow retrograde motion of 50″ 2 per year

53 The distance in degrees reckoned on the ecliptic from the vernal equinox to the foot of the perpendicular dropped on the ecliptic from a celestial body is called its *tropical longitude* In Fig 1 the angle I *ES* (160°) and in fig 3 the arc *OS* are the Sun s tropical longitude

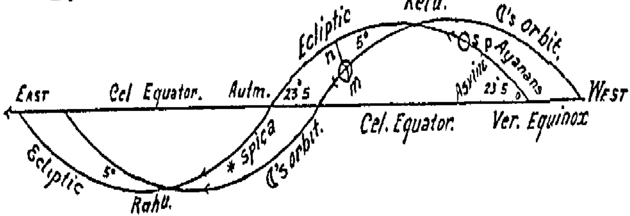
54 The tropical longitude of the first point of Ashvini reckoned in degrees is called *Ayanâmshas* The Ayanamshas according to Munjal increase slowly at the rate of about 59″ per year of which about 8″ 8 are due to the annual shifting eastward of the first point of Ashvini (P) owing to the excess of the sidereal year of Surya S and 50″ 2 due to the actual precession of the Vernal Equinox (O) (Fig 3)

55 The orbit of the Moon cuts the ecliptic in two opposite points called *nodes* The node through which the orbit passes to the northern side of the ecliptic is called *Rahu* and the other is called *Ketu* These nodes have a daily retrograde motion of about 3 (Fig 3)

56 The longitude of that point of the Ecliptic which is in contact with the horizon of a place at a given moment is called the *Lagna* at that moment

57 The independent variable often expressed in angle or time on which depends the value of a dependent variable is called an *Argument* It is always stated at the head of each table and is shown on one or two sides of it

Fig. 3 Illustrating the Definitions.



A table has sometimes two arguments and is then called a table of *double entry* as the Tables 12 28, 35 36 One of them is shown on the vertical side and the other on the horizontal side of the table In this case the quantity to be found out lies at their crossing point

58 The angular correction made to the mean value in order to obtain the true one is called an *equation* or an *inequality* as the angle *EfC* (Fig 2)

TERMS SIGNIFYING TIME

59 The instant when the true Sun arrives at the initial point of Ashvini P (Fig 3), is called the *Meshadi* or Epoch of the commencement of the Hindu sidereal year (Table 3)

60 The time in which the Sun departing from any fixed star returns to the same star is called the *sidereal year* According to the Surya Siddhanta its length is 365 258 756 484 days But according to Prof Newcomb it is 365·256 898 4 days

One-twelfth of a sidereal year is a mean solar month, and the time taken by the true Sun in passing through a given Rashi is the true solar month corresponding to that Rāshi (*Vide Section 70*)

61 *The time that passes between two conjunctions of the Sun and the Moon is called a lunation or a lunar month* Its mean duration is 29 530 587 946 days One thirtieth of a lunar month is a mean tithi or lunar day, and its length is 98435 of a day

62. The period in which the Moon makes one complete revolution with reference to any fixed star is called a *sidereal month* Its length is 27 321 674 160 days

63 The time of the Moon s revolution from apogee to apogee is called an *anomalistic month* Its length is 27 554 599 9 days

64 The time reckoned in ghatis from the apparent Sunrise at a place is called *Savana* It is employed in the performance of the Hindu religious ceremonies

Note—1 day = 60 ghatis, 1 ghati = 60 palas, 1 hour = 2 5 ghatis 1 minute = 2 5 palas and 1 pala = 0 4 of a minute

CHAPTER VIII

THE THEORY OF THE ADHIKA AND KSHAYA MONTHS

(*For practical determination vide* sec. 108.)

65 The *adhika* or the intercalary month is a peculiarity of the Luni-solar calendar and is due to the excess of the solar year over the lunar by 11.0648 tithis. This excess amounts to one lunar month in 32.532 solar months or 7 lunar months in about 19 solar years.

The luni solar calendar is the most ancient and has been in use among the Chaldeans, the Hindus, the Jews and the Chinese. The intercalary months were assigned by them to certain fixed years of their cycles (*vide* secs. 129, 151, 154) and being calculated with mean motions, there was no possibility of a *Kshaya* month.

It were the Hindus, it appears, who first took the bold step of introducing into their calculations the true motions and positions of the Sun and the Moon. But this step opened a doorway for the strange and hitherto unknown *Kshaya* month, i.e., the suppressed month.

66 **Lunar months how named.**—That lunar month in which the Sun enters the Mesha Rashi is called Chaitra; that in which he enters the Vrishabha Rashi is called Vaishakha and so on. The lunar month in which no Sankramana occurs is called *adhika* and bears the same name as that of the next lunar month. That lunar month in which two Sankramanas occur gets two names,* of which the first is retained and the second is suppressed or joined to the preceding.

67 **Importance of the Adhika months.**—Table 2 furnishes all the Adhika and Kshaya months that have occurred or shall occur from Shaka years 0 to 2105. In calculating the ending moment of a given tithi it is absolutely necessary to know beforehand whether the given year contains any Adhika or Kshaya month. For without this knowledge it is impossible to determine the exact number of tithis intervening between the epoch of the Mesha Sankranti and the given tithi. (*Vide* sec. 79.)

* The author has seen at Hubli a manuscript copy of an old panchāng containing a *Kshaya* month. It contained a month having two names joined together as Mārgash rsha Pausha.

68 Prescience of the Adhika months —When the elements for the epoch of Mesha Sankranti are calculated (sec 77) the tithi or the *Tithi Shuddhi** as it is called by way of pre eminence can tell us whether the year contains an Adhika month and if so what month is most likely to become Adhika * An Adhika month is possible only if the tithi Shuddhi is between 19 and 31 and is impossible outs de these lim ts For instance the Tithi Shuddhi for Kali year 0 in Table 3 is 27 795 This Tithi Shuddhi lying between the said limits the year 0 contained an Adhika month which was most probably Jye tha as the next section shows

69 The limits of the Adhika and Kshaya months —The following are the limiting values of tithi-shuddhi within which each of the months shown against them may possibly become Adhika or Kshaya

Note —The limits are common to Surya Arya and Brahma siddhantas alike

Limits of Tithi Shuddhi

Between—29 6—31 2	Adhika	Chaitra is possible
28 2—30 4		Vaishakha
26 4—29 1		Jyestha
24 5—27 3		Ashadha
22 4—25 3		Shravana
20 8—23 3		Bhadrapada
19 8—21 7		Ashvina
19 3—20 6		Kartika
19 3—20 1		Marga Shirsha or Kshaya Kartika
19 4—20 1		Marga Shirsha,
19 5—20 2		Pausha
19 3—20 7	Adhika	Phalguna

Note 2.—The limits of the months Kartika Marga Shirsha and Pausha are nearly equal and as such are of little practical value. It is only after actual calculations of the times of the Sankrantis and new Moons that we are able to decide which of them is Adhika or Kshaya

* The week-day of the Mesha Sankranti is similarly called *Abdapa* i.e the lord of the year

70 A solar month is often called by the name of the Rashi, in which the Sun is moving and its length is the time which he takes to cross the Rashi In the following table are given the names of the lunar month, and the names of the solar months, connected with them in the manner stated in the first sentence of section 66 and also the lengths of the solar months in days according to the Sûrya-siddhânta —

Name of Lunar month	Connected Solar month	Length of Solar month in days	Name of Lunar month	Connected Solar month	Length of Solar month in days
Chaitra	Mesha	30 94	Ashvina	Tula	29 89
Vaishakha	Vrisha	31 42	Kartika	Vrischika	29 49
Jyeṣṭha	Mithuna	31 64	Marga	Dhanu	29 32
Ashadha	Karka	31 48	Pausha	Makara	29 45
Shravana	Sinha	31 02	Magha	Kumbha	29 82
Bhâdra	Kanya	30 44	Phâlguna	Mina	30 35

Note —The lengths of the solar months remain invariable for centuries but those of the Lunar months vary between 29 27 and 29 82 days

71 Aptitude of months for becoming Adhika and Kshaya —A lunar month can become Adhika if the duration of the solar month connected with its preceding month is greater than that of a lunar month and it can become Kshaya if the duration of the solar month connected with itself is less See the preceding section

The 7 months from Phalguna to Ashvin fulfil the first condition only and can on that account become always Adhika but can never become Kshaya The Kartika and Margashirsha months fulfil both the conditions in respect of the limits (29 27 — 29 82 days) of a lunar month but within a very small margin They therefore can become both Adhika and Kshaya but rarely

The month Pausha has almost no chance of becoming Adhika but has a greater chance of becoming Kshaya than the month Margashirsha The month Magha can become Adhika but not Kshaya But the limits are so narrow that it has never become either Adhika or Kshaya

72 The limits of a Kshaya month are so narrow and so nearly identical with those of an Adhika that it is generally preceded and followed though not immediately by an Adhika month, so that there are often two Adhika months when a Kshaya month occurs The shortest period of its recurrence is 19 years in which the change in the tithi shuddhi is only 0 231, but that in the Moon s anomaly is — 50° 3 The other periods of recurrence are 46 65 122 and 141 years made up of multiples of 19 plus 8

Ganesh Daivajna gives in a verse the following Shaka years which contain a Kshaya month according to the Surya Siddhanta 1462 1603 1744 1885 2026 2045 2148 2167 2232 2373 2392 2514 2533 2655 2674 2796 and 2815 He also gives additional Shaka years which contain a Kshaya month when calculated by the Arya Siddhanta They are 1481 1763 1901 2129 2186 and 2251

CHAPTER IX

THE LUNI-SOLAR CALENDAR

According to the Surya Siddhanta

73 This calendar has been in use in India from the earliest time down to the present In its present form probably since Shaka 200 it uses the true positions of the Sun and the Moon instead of the mean ones as in Vedanga Jyotisha Though this was a real advance in the right direction yet it has necessitated troublesome calculations The solar calendar is much simpler to calculate and seems therefore to have been adhered to by our brethren the Bengalees and the South Indians

74 The Sankalpa —*Before proceeding with any religious* ceremony a pious Brahmin must declare solemnly his intention to perform it according to the formula called Sankalpa The *Sankalpa opens with the recital of the chronological order of the* grand divisions and subdivisions of time beginning with the *Shri Shveta Varaha Kalpa* down to the very tithi nakshatra yoga and karana of the day as well as of the geographical position of the place and of the signs occupied by Jupiter and other planets A Panchânga is therefore as much necessary to his religious life as

food and water are to his worldly existence It is thus inseparable connection of Astronomy with the Hindu religion that has saved the former from total neglect

75 The three chief Siddhāntas and the parts of India where they are used —A comprehensive standard work on the theory and practice of Astronomy is called a *Siddhānta* There are three such works *viz* the Surya S° the Arya S° and the Brahma S° The first is used throughout the Indian Peninsula on account of its greater accuracy The second is used in Malabar, Travancore and the Tamil Districts of Madras while the third is followed in Gujerath and parts of Rajputana but is at present being gradually abandoned in favour of the first

76. The Karanas or Manuals —In the Siddhāntas the calculations are made from the Epoch of Mahayuga or of the Kaliyuga, and consequently it is almost impossible to compute a Panchanga directly from any of them Rudimentary tracts called the *Karanas* (not to be confounded with the half of a tithi) based on these Siddhantas have consequently sprung up from time to time, and have been given up in favour of new and better ones At present the Karanas of Surya S° which have been extensively used in Upper India and Bengal are the *Makarand* and the *Ramavinoda* The *Grahalaghava* of Ganesh which is far superior to them is used in Central India and the Deccan Those of the Arya S are the *Laghu karana* the *Karana pralasha* and *the Larahita* These are followed in Malabar and South India. The Karana Kutūhala of Bhaskara follows the Brahma S

TO CALCULATE THE ENDING MOMENT OF A TITHI IN UJJAIN MEANTIME (U M T)

77 Method When the given year is of the Shaka Era, add 78 to it and the sum will indicate the A D year With the century of the A D era as argument enter Table 3 and take down the elements for that century Below them write their increase for odd years given in Table 4 and add up the elements separately The sums will represent the values of the elements at the commencement of the given solar year which is the same as the Moment of Mesh Sankranti otherwise called *Meshadi*

78 Complete the fractional tithi by adding to it its complement in decimal fraction Diminish the complement of the tithi by one sixty fourth part of itself and call the remainder C

Write the value of C below the elements of Vara date and the Sun s anomaly and put zero below those of Rahu and Ayanamsha when they are required (*vide* sections 162 169 175)

Multiply C by 13 and place the product below the element of the Moon s anomaly as degrees

Add up all the elements separately and denote them by S This part of the working is called the *completion of the Tithi Shuddhi* whereby we obtain the values of the elements at the ending moment of the tithi Shuddhi

79 Refer the Shaka year to Table 2 and see if it contains any Adhika or Kshaya month Then count the number of tithis elapsed from the beginning of the Luni Solar year (which begins on the first tithi of Chaitra) to the end of the given tithi taking into account the 30 tithis of the Adhika month and omitting the 30 tithis of the Kshaya month if there be any, and denote the total by T

Deduct from T the completed tithi shuddhi S, and call the remaining tithis R Thus $T-S = R$ and $S+R = T$

Enter Table 5 with R as argument write the increments below the elements denoted by S and add them separately The sums will be the mean elements at the ending moment of the given mean tithi T

80 *To obtain the ending instant of the true Tithi as seen from the Earth's centre, and the English date corresponding to it*

Enter *Table 6* with Sun s anomaly as its argument take out the Sun s equation of centre expressed as fraction of a day, and place it below the Vara and English date

Multiply the Sun s equation by 12 (more correctly by 12 2), put the product as degrees below the Moon s anomaly and add them up

With this corrected anomaly of the Moon, enter Table 7, take out the Moon's equation of centre, and place it below Vâra and date.

Add up the three quantities according to their signs. The integers of Vâra indicate the number of the *Week day*: one indicating Sunday, two indicating Monday, and so on.

Multiply the fraction of the Vâra by 60, and the integers of the product will denote the ghatis. Multiply again the fraction of ghatis by 60, and the product will represent the number of palas.

Thus we arrive at the *Vâra ghatis* and *palas*, of the time when the tithi ends.

81 *To determine the English month and date*.—All that one has to do now is to refer to Table 11 and find out the highest number of days that can be subtracted from the total of days, calculated in the column headed "A D date" and to subtract them. The remainder will show the month and date of the Christian Era, the year being shown in the third column of the working. (*Vide* Sec 82, type of calculation.) The year should be increased by unity when the date passes December 31.

Note 1.—The English date is here supposed to begin at mean sunrise of Ujjain.

On referring to Table 2 we see that in 1831 the month Shrâvana was adhika Counting this adhika, which precedes Mâgha we obtain 11 for the number of months elapsed since the beginning of the Luni Solar year 1831 Consequently the required tithi is the $(11 \times 30) + 18 = 348$th from the beginning —This is denoted by T in the following working,—

TYPE OF CALCULATION

Tithi—Mâgha Krishna 3 of Shaka 1831

Explanation.		Shak year	A D year	Tithi	Vâra	A D date	☾ s anom	☉ s anom
Tab	3	1822	1900	13 027	5 670	4 12 620	7° 50	280° 60
	4	8	8	28 518	3 070	0 070	16 80	0 00
	4	1	1	11 065	1 259	0 259	97 09	0 00
At Meshadi.		1831	1909	22 610	2 949	4 12 949	116 39	280 60
Complement				390	0 384	0 384	4 99	38
S the completed tithi				23	3 333	13 333	121 38	280 98
				300	1 306	295 306	259 20	291 00
Tab 5 Arg R 325				20	5 687	19 687	257 20	19 40
				5	4 922	4 922	64 30	4 80
T, the desired mean tithi				348	1 248	333 248	341 08	236 18
Tab. 6 Sun s Eqn Arg 236° 2					+ 149	+0 149	+1 78	+ 149×12
Tab 7 Moon s Eqn Arg 342° 9					— 133	—0 133	342 86	= + 1 78
End of the desired true tithi T					1 264	333 264		
Tab 11 April 0 to Feb 0						306		
Engl date A D 1910 Feb Sunday						27 264 = 15 gh		50 palas
The same by D B Pillai						27 264 = 15 gh		50 palas

EXPLANATION

83 The computation upto the elements of the desired mean tithi T is too easy to require explanation We then enter Table 6 with Sun s anomaly 236° 18 as its Argument and take out the *Sun's equation* + 149 day and write it below the Vara and date

We then multiply the Sun s equation +0 149 by 12 and add the product + 1° 78 to the Moon s anomaly 341° 08 and obtain 342° 86 With this value of Moon s anomaly we enter Table 7 and obtain —0 133 day for the *Moon s equation* of the centre,

and we write it below that of the Sun in the columns of Vara and date Lastly we add up the three quantities according to their signs and get Vara 1 264 is the *ending moment* of the required tithi

The integer 1 in the Vara indicates that the tithi ended on a Sunday The fraction 0 264 multiplied by 60 yields 15 84 ghatis and the fraction 0 84 multiplied by 60 yields 50 palas So the result is that the tithi *Magha Krishna 3 of Shaka year* 1831 *ended on a Sunday at* 15 *gh and* 50 *pala after the mean Sunrise at Ujjain* Fractions of a day are easily converted into ghatis and palas by means of Table 40

This result is in complete agreement with that obtained by D B Pillai in his Chronology page 15

84 The English date – In the column for date we have A 333 days By referring to Table 11 under April we see that the highest number that can be subtracted from 333 is 306 upto the end of January or February 0 This being subtracted we get 27th of February 1910 because the year 1909 ended on December 31 and the year 1910 commenced on January 1

Note –The method of converting the meantime of Ujjain into the time reckoned from the true Sunrise of any place is explained in Chapter XVI

CALCULATION OF THE ENDING MOMENT OF A NAKSHATRA

85 Connected with a month and Tithi —A nakshatra or a yoga unless connected with any lunar month has *no significance* at all We shall therefore explain here how to calculate the ending moment of a nakshatra concurrent with a given tithi at mean sun rise (*Vide* Section 116)

86 Definition —A tithi counted from the preceding New Moon of a current month is a *monthly tithi* while the same counted from the beginning of Chaitra is called an *annual tithi* In the present example 18 is the monthly tithi and 348 is the annual tithi

Note —Here the words tithi and yoga should be understood to mean the spaces indicated by them and not the times

87. Method.—Put the monthly tithi and the Sun's anomaly into their places in the following formula, and solve it for the nakshatra. The nakshatra thus derived will be running at the moment indicated by the Vâra of the mean tithi T.

$$\frac{3}{40}\left\{(12^\circ \times monthly\ tithi) + \odot\text{'s } anom + 77^\circ\ 26\right\} = Nak$$

Then in place of the annual tithi T, in the preceding calculation, put the fractional nakshatra, and retain only the Moon's anomaly, omitting the Sun's anomaly as unnecessary.

Complete the fractional nakshatra by adding to it its decimal complement. Increase this decimal complement by one eightieth part of itself and then add it to Vâra.

Multiply the increased complement by 13 and add the product to the Moon's anomaly as degrees.

With the Moon's anomaly take out from Table 8 the Moon's equation for Nakshatra and add it to the Vâra.

The result will be the *ending moment* of the completed nakshatra from the mean Sunrise of Ujjain.

88. Example.—Find the ending moment of the nakshatra current with Mâgha Krishna Tritiyâ of Shaka year 1831.

Putting the monthly tithi 18 and the Sun's anomaly 236°·18 into the preceding formula and solving it for nakshatra, we get 12·708 as mean nakshatra current with the 18th tithi. The fraction ·708 belongs to the 13th nakshatra which is named Hasta (*Vide* the Appendix.)

CALCULATION OF THE ENDING MOMENT OF A YOGA

89 Method —It is similar to that of a nakshatra Calculate the current mean yōga by the following formula employing in it the mean nakshatra, obtained by the formula of Section 88

$$2 \times \textit{nakshatras} - 0.9 \times \textit{monthly tithis} = \textit{yoga}$$

Put this yoga in place of the tithi as before Complete it by adding to it its decimal complement Diminish the complement by one seventeenth (17th) part of itself and add it to Vara and to the Sun's anomaly Multiply the diminished complement by 13 and add the product in degrees to the Moon's anomaly

Then with the Sun's anomaly take out from Table 9 the Sun's equation of centre and write it under the Vara

Multiply the Sun's equation by 14 and add the product in degrees to the Moon's anomaly with the Moon's anomaly thus corrected take out from Table 10 the Moon's equation and write it below that of the Sun Then add up the Vara and the two equations according to their signs

The result will be the *ending moment* of the completed yoga from the mean Sunrise of Ujjain

90 Example —Find the ending moment of the yoga concurring at mean Sunrise with Magha Krishna 3 of Shaka year 1831

First we calculate the current yoga by the above formula of Section 89 and get for it 9.216 the fraction .216 belongs to the yoga Ganda (*Vide* the Appendix)

$$(2 \times 12.708) - (.9 \times 18) = 9.216 \text{ yogas}$$

Type of calculation of a Yoga

Explanation	Yoga	Vara	☾'s anom	☉'s anom
Yoga current at T	9.216	1.248	341° 08	236.18
Complement	.784	.738	9.59	.74
Ganda Yoga	10.000	1.986	350.67	236.92
Tab 9 Arg 237° Sun's equation		−.061	−0.85	−.061 × 14
Tab 10 Arg 350° Moon's equation		−.067	349.82	= −0.85
Ganda Yoga ends Sunday		1.858	= 51 gh	29 palas

Take this round number for R and calculate, as before the ending moment of the resulting tithi, $S + R = T$

Should the tithi T thus found, end on either the preceding or the following date, the number of the tithi should be corrected so as to tally with the given date.

For instance suppose that it is required to calculate the tithi which concurs with the Sunrise of the English date, Sunday, the 27th of February 1910

In the example of Section 82 the completed tithi shuddhi S is 23 and the date is April 13·333 We know from Table II that the period from April 0 to 27th February is $306 + 27 = 333$ days

Subtracting 13 333 days from 333 days we get 319·667 days Dividing these by 63 we get 5·074 as quotient Adding 319·667 and 5 074 we get 324 741 or in round number 325 tithis, which represent R in this instance

With this R we proceed as in the example of Section 82, and arrive at the result that $23 + 325 = 348 = T$ which was Mâgha Krishna 3 of Shaka year 1831 as Shrâvana was adhika in 1831 by Table 2

THE MOST ANCIENT TITHI MENTIONING THE WEEK-DAY

94. Example 2.—Calculate the ending moment of Ashâdha Shukla dwadashi, Thursday, in Kaliyuga year 3585 or Shaka year 406

This is the celebrated test problem selected by Mr Dixit and others in their works on Chronology. The date appears on a pillar erected by the king Budha Gupta at *Eran* (Lat 24° N Long 78° 15' East from Greenwich) in the Central Provinces It is the oldest inscription that mentions the week-day along with the tithi

We conclude from Table 2, that Shaka year 406 contained no adhik month, and, therefore, the tithi was 102nd from the beginning of the Shaka year 406. Also the tithi-shuddhi 5·222 in the working, supports the conclusion. (*Vide* Section 68)

Ashâdha Shukla 12 *of Shaka year* 406.

Explanation	Shaka year	A D year	Tithi	Vâra	A D. date	• anom	☉'s anom
Tab 3 . ..	322	400	5 777	0 486	M.17·486	104° 20	280° 6
" 4	84	84	29·445	0 735	0 735	175 93	0 0
At Meshâdi ..	406	484	5 222	1·221	M.18 221	280·13	280·6
Complement ..	..	..	·778	·776	·776	9 96	·8
S. completed tithi	..	..	6	1·987	18·987	290·09	281·4
Tab 5 Arg R. 96	..	..	90	4·592	88·592	77·50	87·3
			6	5·906	5·906	77·20	5·8
T. Ashâdha 12	..	..	102	5·485	113·485	84·79	14·5
Tab 6, Arg 14·5, ☉'s eqn	..	..	..	—·046	—·046	—·55 =	—·046
Tab. 7, Arg 84 24 ☾'s eqn.	..	..		+·414	+·414	84·24	× 12
End of Ahsâdha 12	..	..	..	5·853	113·853	= 51 gh	11 pa
Tab. 11, March 0. to June 0					92·		
Engl date A.D. 484 June			..	Thurs	21·853		
By D. B Pillai, Chron. agege			..	..	21·853	= 51 gh.	11 pa

The above calculation shows that Áshâdha Shukla 12, Shaka year 406, ended on a Thursday at 51 gh. and 11 palas, and that the English date on that day was June 21 A D. 484.

The week-day, Thursday, confirms the truth and genuineness of the Inscription.

95 We shall now calculate the *nakshatra* and *yoga* of this memorable date according to Sections 87—91.

By Sections 87 and 89—

$\frac{1}{4}\,|(12^\circ \times 12) + 14^\circ\cdot 5 + 77^\circ\cdot 26\,| = 17\cdot 682$ Nakshatra.

$|\,(2 \times 17\cdot 682) - (0\cdot 9 \times 12)\,| = 24\cdot 564$ Yoga.

Calculation of the Nakshatra on Ashâdha 12, Shaka 406

Explanation	Nakshatra	Vara	☾'s anom
At the end of 10[illegible] tithi Complement	17 68° 318	5 485 319	34° 79 4 16
This Nak falls on Friday *By Sec 91 and Table 18*	18 *—1*	5 804 *—1 012*	88 95 *—13 22*
Anurâdhâ	17	4 792	75 73
Tab 8 Arg 75° 73 ☾'s eqn		+ 377	
End of Anurâdhâ at By D B Pillai Chro page 12	10 gh 8 p 10 gh 1[illegible] p	5 169 5 170	Thursday

96 Next let us calculate the yoga

Calculation of the Yoga on Ashâdha 12 Shaka 406

Explanation	Yoga	Vara	☾'s anom	☉'s anom
At the end of 10[illegible] tithi	[illegible]4 570*	5 485	84 9	14 5*
Complement	430	405	[illegible]	4
Yoga ends next day	[illegible]5	5 890	90 0	14 9
Sec 91 Table 18	—1	[illegible]	1[illegible] 3[illegible]	— 0
Shukla Yoga	4	4 949	77 75	14 0
Tab 9 Arg 14° ☉'s eqn		+ 38	+ 56	= { + 040
Tab 10 Arg 78 ☾'s eqn		355	8 31	× 14
Shukla ends Thursday		5 [illegible]	[illegible] gh	31 pa
By D B Pillai Chro page 1[illegible]		5 [illegible]	[illegible] gh	[illegible]4 pa

97 Calculation of the Christian date on which Buddha died B C 483, Kartika Shukla 8 —The date appears in an article by Dr Fleet in the Journal of the Royal Asiatic Society for 1909 We shall work out this problem as an illustration of the method of calculating a tithi occurring in B C years, which lie beyond the limits of Table 2

In the working of this example below, the tithi Shuddhi, *i e*, the tithi at Meshadi is 26 6 It falls within the limits of possibility of adhika Jyestha (*vide* Section 69) which precedes Kârtika The number of months elapsed since Chaitrâdi is therefore, 8 and the tithi in question is 248th

In Table 3 the year B C 483 lies between B C 501 and B C 401 and commences 18 years after B C 501

Note—B C years are to be considered as minus They succeed in the descending order

Calculation of the Christian date of Buddha's death

Kârtika Shukla 8 Shaka — 560 October 13, B C 483 Tuesday

Explanation	Shaka year	B C year	Tithi	Vâra	B C date	☾'s anom	☉'s anom
Tab 3	—578	—501	7 427	1 605	M 9 605	10° 23	250° 6
4	16	16	27 037	6 140	0 140	33 51	0 0
4	2	2	22 130	2 517	0 517	184 19	0 0
At Meshâdi	—560	—483	26 594	3 262	M 10 262	236 93	280 6
Complement			406	400	400	5 20	0 4
S completed tithi			27	3 662	10 662	242 13	281 0
Tab 5 R 221			200	0 871	196 871	52 10	194 0
			20	5 687	19 687	257 20	19 4
			1	0 984	0 984	12 86	1 0
T Kârtika Sh 8			248	4 204	228 201	204 33	135 4
Tab 6 Arg 135° 4				— 127	— 127	—1 51	— 127
Tab 7 Arg 202 8				— 149	— 149	202 80	x12=
Kârtika Sh 8 ends				3 928	227 928		—1 53
Tab 11 Mar 0 to Oct 0					214 000		
Date B C 483 Oct 13 Tuesday					13 928	55 gh	41 pa
By D B Pillai Oct 13 Tuesday					13 920	55 gh	12 pa

98 In the above example we have assumed, on the strength of Section 69, that Jyestha was adhika in B C 483 We shall now show from actual calculation that our assumption was a fact

We take down the following elements for the Meshadi of B C 483 from the preceding working

Calculation of Adhika Jyestha in B C 483

Explanation	B C year	Tithi	Vâra	☾ s anom	☉ s anom
At Meshadi	483	26 594	3 262	236° 93	280° 6
Tab 13 increase for Mithuna		63 347	6 356	94 60	61 5
Mithuna S begins		89 941	2 618	331 53	342 1
Complement		0 059	058	0 75	0 1
3rd New Moon		90	2 676	332 28	342 2
Tab 6 Arg 342° 2 ☉ s Eqn			+ 056	+0 67	+ 056
Tab 7 Arg 332° 95 ☾ s Eqn			— 204	332 95	× 12
Time of 3rd New Moon			2 528		= + 67

It is quite obvious from the above figures that the Mithuna (3rd) Sankranti occurred at 2 618 and that the third New Moon (Amanta) fell on the same day at 2 528 *i e* (2 618 — 2 528) = 0 09 day or 5 4 ghatis before the beginning of Mithuna

Deducting 0 09 day from the period of the Vrishabha Sankranti (*vide* Table 13) which is 31 42 days we get 31 33 days which exceeds the duration of the longest lunar month 29 81 (*See* Note to Section 70) Consequently no Sankranti did occur between the 2nd and the 3rd New Moon and the month Jyestha was undoubtedly adhika in B C 483

99 Problem —To calculate the English date on which the Sun attains a given tropical longitude

Example —Required the English date of the Summer Solstice in B C 483 on which the Buddhist holiday of *Vassa* was held

The Summer Solstice occurs at the moment when the Sun s tropical longitude is exactly 90° But our Hindu year being sidereal we have been all along working with the sidereal longitudes without ever feeling the need for tropical longitudes So we must have now some link for connecting the sidereal and tropical longitudes. This is furnished by the precession of the

Vernal equinox called the Ayanamshas In other words the Ayanamshas are the tropical longitude of the first point of Ashvini (Section 54)

Table 3 contains the Ayanamshas They are meant to be applied *to the sidereal longitudes for converting them into the* tropical ones But in the above example we have to do the opposite They must therefore be applied to the tropicol longitudes with their sign changed to get the sidereal ones

From Tables 3 and 4 we obtain — 16° 48 of precession or Ayananashas for B C 483 These applied with the sign changed to 90° give 106° 48 for the Sun s sidereal longitude at the moment of the Summer Solstice in B C 483

The problem then comes to this—To find the English date in B C 483 on which the Sun s true sidereal longitude was 106° 48—This is solved in the following manner, remembering that the mean longitude (sidereal) of the Sun at the moment of Mesha Sankranti is always 357° 86 owing to his apogee being considered fixed (See Secs 190 and 192)

Date of Summer Solstice in B C 483

Explanation	B C year	○ s longitude (8)	○ s anom	Date (9)	T this Tab 18
				days	
At Meshâdi Example Sec 97	483	357 9	[illegible]80 6	M 10 26	26 0
Table 5 Col (8) (9) motion		100 0	100 0	101 50	103 0
Do do do		8 0	8 0	8 10	8 1
Do do do		0 6	0 6	0 60	0 6
Mean longitude		106 [illegible]	29 [illegible]	120 46	138 3
Table 31 Arg [illegible]9° 2 ○ s eqn	—1° 0	changed to	+1 0		
Do 30° 2 ○'s eqn	—1 1		30 [illegible]	+1 10	0 0
Total days from March 0				1[illegible]1 56	138 3
Table 11 days from March 0 to June 0				9[illegible] 00	1[illegible]0 0
Date of the Solstice B C 483 June			Old Style	[illegible]9 56	18 3
By D B Pilla s calculation Chro page 5				[illegible]9 59	Sec 152e

The reason of adding the Sun's equation of centre to the anomaly with its sign changed is to account for the change in the Sun's equation which influences the time of the Sun's attaining the required true longitude.

Note.—In the Old Style the Solstices recede on the dates as the years advance. To stop the recess is the main object of the New Style, which has since its adoption fixed 21st June as the day of the Summer Solstice. Before the reformation in the Calendar of Julius Cæsar it was 25th June.

100 The later Sûrya Siddhanta has been the *Almagest* of India for the last 15 centuries and has been acknowledged as authority in matters astronomical. Almost all the subsequent works on astronomy have been more or less based on it and it is much venerated in India as being a direct revelation from the Sun. (*Vide* Sec. 207.) As all the past civil and religious transactions have been guided by the Panchangas conforming to it, it is absolutely necessary for the Epigraphist to use them as searchlight in his difficult work of verifying and fixing the dates of ancient events.

But it would be *unreasonable* to adhere to it in future when the great discoveries, the accurate observations and the refined methods of calculation of modern European astronomers are available to us. We must venerate and admire it as an ancient relic testifying to the highest degree of excellence attained by the ancients under very adverse circumstances. [*Vide* Chap. XVII, Note 15 (d).]

Already Panchangas based on the Nautical Almanac have gained considerable popularity among the educated men for their perfect agreement with the easily observable phenomena, such as the eclipses and conjunctions of planets. But however accurate the calculations of the Nautical Almanac may be, it would be *unwise* to remain permanently dependent on it, as it is in itself

an annual publication We must have our own works on astronomy, prepared in the light of modern researches and discoveries

The last Indian Astronomer worthy of the name was *Ganesh Daivajna* who wrote his famous *Grahalâghava* in the year A D 1520, *i e*, exactly four centuries ago He has united in his book both accuracy and ease, the most desirable qualifications of a *Karana* to such a degree that no one has since been able to surpass him He has well maintained the respectable position conferred on him by posterity

But unfortunately he lived in an age long before the dawn of modern Astronomy The Copernican Solar System Kepler's laws Newton s law of gravitation the invention of the telescope, the theory of perturbations developed by Lagrange and Laplace, the lunar theory perfected by Hansen, Delaunay and Newcomb, the discovery of the new planet Neptune from the perturbations of Uranus by Leverrier and Adams, these are the triumphs of Modern Astronomy which were not even dreamt of in his time

The present author thinks that it would not be considered out of place to mention here, that he has done his best to fill up the gap of these four centuries by securing for his country men, *the benefit of* the later Western discoveries He has composed in A D 1898 works in Sanskrit called *Jotirganitam, Ketaki and Vaijayanti*, in which he has based his calculations on the elements and constants determined by Leverrier, Hansen and Newcomb But almost all the tables in his *Jyotirganitam* had to be reconstructed so as to suit the Hindu method of calculation He has composed 7 other works in Sanskrit and Marathi on such subjects as the problem of two bodies *the theory of elliptic motion the path* of the Moon s penumbra on the surface of the Earth, the star atlas and the like The example of a tithi worked out in the next Section will, it is hoped, testify to the accuracy accomplished in his Jyotirganitam

101. Problem.—To calculate the ending moment of a tithi from the corrected elements of Sûrya Siddhânta so as to agree, within a few palas with that obtained directly from the Nautical Almanac.

Method.—Calculate the mean ending moment of the given tithi T according to Sections 77, 78 and 79.

Add to the elements of Vara, the English date and the Moon's anomaly the following *constants* of correction, *viz.* + 0 014, + 0 014 and + 3° 33 respectively. These constants will serve for the next one or two centuries. The Sun's anomaly requires no correction whatever.

102. *Then as before enter Table 6 with the Sun's anomaly,* take out the Sun's equation, and write it below the Vara and the date of the mean tithi T.

Multiply the Sun's equation by 12 and add the product in degrees to the Moon's anomaly. Deduct from this corrected anomaly of the Moon the product of the monthly tithi by twelve *i.e.* 12° × monthly tithi (see the definition in Section 86) and the remainder will be the vertical argument of Table 12. The monthly tithi itself should be taken for its horizontal argument.

Table 12 is an instance of double entry. When the monthly tithi lies at the top we should enter the Table with the vertical argument commencing at the left hand top-corner and take out the Moon's equation with the left hand sign attached to it. But when the monthly tithi lies at the bottom, we should enter it at the right hand bottom corner and take out the equation with the right hand sign attached to it as is done in the next example.

103. **Example**.—We will calculate the ending moment of Nija Shrâvan Krishna Shasthi 6 of Shaka year 1831. The difference between the ancient and modern tithis is greatest about the 9th and 21st monthly tithis for a given Sun's position from the Moon's apogee. Here the monthly tithi is the 21st

Type of Calculation

Explanation	Shaka year	A D year	Tithi	Vâra	A D date	☾'s anom	☉'s anom
Tab 3	1822	1900	13 027	5 620	A 12 620	7 39	280° 6
4	8	8	28 518	3 070	3 070	16 76	0 0
4	1	1	11 065	1 259	0 259	92 09	0 0
At Meshâdi	1831	1909	22 610	2 949	12 949	116 25	280 6
Complement			390	384	384	4 99	4
S. Completed tithi			23	3 333	13 333	171 24	281 0
Tab 5 Arg R 148			100	0 435	98 435	206 10	97 0
			40	4 374	39 374	154 40	38 8
			8	0 875	7 875	107 90	7 8
T mean tith Shrâ 21			171	2 017	158 017	224 64	64 6
Correction Sec 101				+ 014	+ 014	−3 33	0 0
Jyotirgan ta Shrâ 21			171	2 031	158 031	224 9	64 6
Tab 6 Arg 64° 6 ☉s Eqn				− 161	− 161	−1 93	−0 161
						226 04	×12
21 × 12° = 252 ☾ − ☉						−252 00	= −1 93
Tab 12 Arg 334° ☾ s Eqn				− 495	− 495	334 04	
True tithi ends				1 375	158 375		
Tab 11 April 0 to Sept 0				days	153		
Sept 5 Sunday True tith ends at					5 375 = 22 gh		30 pa
By N Almanac					5 367 = 22 gh		2 pa
By D B Pillai					5 403 = 24 gh		18 pa

Note—The reader will note that the method of Jyotirganita is direct and not hampered by successive approximations

The ending moment of the tithi comes to 22 gh and 2 pa when worked out with the data of Nautical Almanac using the method of Interpolation

Our Table 12 is taken from our Jyotirganitam It is formed by the combination of the Variation Evection the equation of centre of the Moon and a few minor inequalities depending upon the combinations of the different multiples of the Moon's anomaly and elongation

104 *Karanas*—The Karanas (Section 25) are the halves of the tithis So there are 60 Karanas in a Lunar month Their number is made up by the repetition of the 7 Karanas eight times

in a lunar month beginning with the second half of the Shukla pratipada which is called *Bava* and ending with the first half of the Krishna Chaturdashi which is called *Bhadra* or *Vishti*. The remaining four Karanas are immovable. See the Appendix.

Their calculation.—The ending times of the Karanas which are assigned to the second halves of each tithi coincide with those of the tithis themselves and therefore there is no need for their calculation. The ending times of the first halves or Karanas of tithis are got by adding the Vara, ghatis and palas of two consecutive tithis successively and dividing the sums by two.

In a Panchanga the ending time of that Karana alone is shown which is current at sunrise.

CALCULATION OF TITHIS
According to the Arya and Brahma Siddhantas

(*Special Tables* 14 *and* 16 *to be used*)

105. These two Siddhantas have been in use only since the beginning of the 4th century of the Shaka Era. As their constants are almost identical with those of the Surya Siddhanta (*vide* Table 37), it is not considered advisable to prepare all the foregoing tables for each of them except the table of elements for the centuries. We have therefore prepared Tables 14 and 16 to be substituted for Table 3 of the Surya Siddhanta in the calculation of the tithis etc. and Tables 15 and 17 to be substituted for Table 13 in the calculation of Sankrantis according to the Arya and Brahma Siddhantas respectively. The rest of the Tables 4-10 are to be used as before.

The Siddhanta Shiromani of Bhaskaracharya has, we believe, never been used as a basis of Panchangas. It occupies the highest place among theoretical works and is often quoted as authority on points of theory only. His *Karana Kutuhala* has been thrown into back ground by the Grahalaghava of Ganesha. So it is of little use to prepare tables based on the constants of Shiromani. Bhaskaracharya was an admirer and follower of Brahmagupta.

106. As an example we shall calculate below, the ending moment of the famous tithi Ashadha Shukla 12, of Shaka year 406 or A.D. 484 by making use of the elements of the two Siddhantas.

According to the Arya Siddhânta

Ashadha Shukla 12 *Shaka* 406.

Tables	Shaka	A D	Tith	Vara	A D March	☾ s anom	☉ s anom
	Year	Year		Days	Days	Degrees	Degrees
14	422	500	7 283	0 361	18 361	309 13	280 0
4	—16	—16	—27 037	—6 140	—0 140	—33 51	0 0
At Meshad	406	484	5 246	1 221	18 221	275 6	280 0
Complement			754	742	742	9 65	0 7
	S		6	1 963	18 963	285 27	280
5	R		90	4 592	88 592	77 50	87 3
			6	5 906	5 906	90	5 8
	T		102	5 461	113 461	79 97	13 8
6 Arg 14° S n s eqn				043	—0 043	—0 53	{— 043
7 Arg 79 5 ☾ S eqn				+ 412	+ 412	79 45	×12=
40 Thurs 49 gh 48 pa				5 830	113 830	June 1	—0 57
See infra							

According to the Brahma Siddhânta

Ashadha Shukla 12 *Shaka* 406

Tables	Shaka	A D	Tith	Vara	A D March	☾ s anom	☉ s anom
	Year	Year		Days	Days	Degrees	Degrees
16	422	500	1 35	6 461	17 461	296 67	280 6
4	—16	—16	—27 03	—6 140	— 140	—33 51	0 0
At Meshad	406	484	4 320	0 321	17 321	263 11	280 6
Complement			680	6 0	6 0	8 71	7
	S		5	0 991	17 991	271 87	281 3
5	R		90	4 592	88 592	77 50	8 3
			7	6 890	6 890	90 06	6 8
	T		10	5 473	113 473	9 32	15 4
6 Arg 15° 4 ☉s eqn				— 04	— 04	— 56	{— 047
7 Arg 78° 8 ☾s eqn				+ 411	+ 411	8 6	×12=
40 Thurs 50 gh 13 pa =				5 837	113 837	June 21	—56
11 March 0 to June 0 days					92		
					1		

Note—The ending times calculated by Diwan Bahadur L. D Swami Kannu Pillai are exactly the same as the above ones

107 The Ekadashi Fast.—The Mâdhvas and Vaishnavas in the Karnataka are strictly enjoined by their Spiritual Gurus to follow the Ârya Siddhanta in the observance of the fortnightly Fast of Ekadashi. This partiality for the Ârya Siddhânta is probably due to the fact that both Aryabhatta and Shri Madhvacharya were natives of Malayalam.

But the elements of the Ârya Siddhanta not being accurate enough (compare Tables 3 and 14) the Arya Siddhanta Tithi ends at present (A D 1920) 3 gh 50 pa later than the Surya Siddhânta Tithi. For this reason the Surya Siddhanta Panchangas have been in general use throughout the Karnataka and the Ârya Siddhanta Panchânga is nowhere followed except at Udipi which is the Holy place of Madhvism in South Canara.

The day being supposed to begin with the 56th ghati for religious purposes there is the possibility of the Ârya Siddhânta Ekâdashi being contaminated by the touch of the Dashami when the Sûrya Siddhanta Dashami ends at about 52 ghatis. This is the occasion for the most scrupulous care in the calculation of the ending moments of the three tithis beginning with the Dashami exclusively with the Ârya Siddhanta elements. This is generally done with the help of the Karanaprakasha. But in obedience to the precept of Vidyadhisha Muni the Rekhantara correction must be omitted in the calculation of the Savana Time.

Example.—We shall calculate Pausha Krishna 12 of Shaka year 1841 for the latitude of Bijapur *i.e.* 17° North. This was the occasion of a protracted *i.e.* Atirikta Ekadashi when the fast lasted 2 days & produced a general agitation among the Madhvas.

Pausha Krishna 12 *Shaka year* 1841

Explanation	Shaka	Tithi	Vâra	☾'s anom	☉'s anom
Tab 14 Ârya	1822	1? 855	5 514	7° 73	280° 00
4	16	27 037	6 140	33 51	0 00
4	3	3 194	3 776	°76 28	0 00
At Mesbâd	1841	13 086	1 430	317 52	290 00
Complement		914	900	11 70	0 90
5		14	2 330	329 22	280 90
Tab 5	R	900	0 871	52 11	194 03
		80	1 748	308 84	77 61
		3	2 953	38 58	2 91
T Pausha	vadi 12	[illegible]	0 907	8 75	195 45
Tab 6 Arg	195° 4	☉'s eqn	+ 048	+0 58	+ 048
Tab 7 Arg	9° 3	☾'s eqn	+ 075	9 33	×12=58
The tithi ends (U M T)		Sunday	1 035	=1 gh	30 pa

We must now calculate the corrections to be applied to the above meantime to reduce it to the duration from Bijapur Sunrise by Section 182. The equinoctial shadow for 17° is 3 7 by Table 34.

We first calculate the Sun's tropical longitude by Section 173.

Sun's anomaly in the above example	195° 45
apogee	77 26
equation	0 05
The precession Tabs. 3 4	22 83
Tropical longitude of Sun	295 59
Then we obtain from Table 33—	gh p
Arg 195° 45 Bhujântar	—0 5
Arg 295 59 gives —18 33pa —18 33 × 3 7 shadow	
= Chara	—1 6
Meantime of ending moment	1 30
Time from Bijapur Sunrise	0 19

The result shows that Dwadashi ending 19 palas after the Sunrise the Ekadashi was *Atiriktâ* so that the fast had to be observed for two days.

CHAPTER XI

THE SOLAR CALENDAR

Sankrantis, Adhika and Kshaya Months, and Solar dates

(According to the Surya Siddhanta)

108 The Sankrantis —When the tithi Shuddhi and the Vâra specially called *Abdapa* at the moment of Meshadi for any given year is obtained by Section 77 the mean tithi and Vara of the remaining Sankrantis are obtained by adding to them the increase upto the beginning of each Sankranti given in Table 13. This is exemplified in the calculation of the Adhika months.

Adhika Months —Calculate the elements for the Meshâdi of the given year by Section 77. Refer the tithi Shuddhi to Section 69 and find out the probable Adhika month

Refer the probable adhika month to Section 70 and find out the preceding and the connected Sankrantis of the probable adhika month

Write the elements of Meshâdi in two places and add to them separately as given in Table 13 the increments upto the beginning of the preceding and current Sankrantis

Then calculate by Sections 78 79 80 the ending moment of the nearest Amanta i e the New Moon using Table 5 and negative complement where necessary

Thus you get the ending moments of two consecutive Sankrantis and Amantas

Write these four results in the order of their occurrence If the Amantas lie between the Sankrantis then the assumed month is adhika *de facto* If not the preceding or the following month should be treated as above

In the determination of a Kshaya month a series of consecutive Amantas and Sankrantis beginning with Kartika, must be calculated and arranged in the order of their occurrence, before it is possible to determine the Adhika and Kshaya months by the Definitions of Section 66

Fortunately the Kshaya months are of very rare occurrence

Example —Calculate the Adhika Shravana of Shaka year 1831 See Ex Sec 82 We must calculate the Karka and Sinha Sankrantis here

Time of Karka Sankranti and 4th Amanta

Explanation	Shaka	Tithi	Vâra	☾ s anom	☉ s nom
				°	°
At Meshâdi Tab 13 Karka motion	1831	*22 630 95 494	2 949 3 000	116 49 148 10	280 60 92 90
Karka Sankrânti time of Complement		118 124 876	5 949 862	264 49 11 20	13 50 86
Tab 5 R		119 1	6 011 984	275 69 12 86	14 36 0 97
Tab 6 Arg 15 3 ☉ equation Tab 7 288 5 ☾ s equation		120	6 995 — 047 — 403	288 55	15 33
Time of 4th Amanta			6 545		

* The correct number for tithi is 22 610 See example of Section 82

Time of Sinha Sankrânti and 5th Amânta.

Explanation	Shaka	Tithi	Vâra	☾'s anom	☉'s anom.
At Meshâdi	1831	*22·630	2·949	116·39	230·60
Tab 13, Sinha.. ..	..	127 470	6 476	199·30	123·70
Sinha Sankrânti, time of ..	..	150·100	2·425	315·69	44·30
		—·100	—·100	—1 30	— 10
		150	2 325	314 39	44·20
Tab 6, Arg 44, ☉'s equation	..	.. ..	—·135		
Tab 7, Arg 314 ☾'s equation	..	.. ..	—·316		
Time of 5th Amanta . ..	..	.. ..	1·874		

ORDER OF OCCURRENCE

Karka Sankrânti ..	Thursday	.. 5·949 Âshâdha.
4th Amânta ..	Friday	.. 6·545 } Adhika
5th Amânta ..	Sunday	.. 1·874 } Shrâvana.
Sinha Sankrânti ..	Monday	.. 2·425 Nija Shrâvana

Note.—The Shrâvana is adhika, there being no Sankrânti between the 4th and 5th Amântas.

The Solar Calendar

109 *Explanation*—The present Indian solar calendar is in principle the same as the Christian calendar, both depending on the period of the Sun's revolution, which is sidereal in the former and tropical in the latter.

The duration of a month in the former is the time which the Sun takes to go over each sign or Râshi, and consists of fractional and integral days; while that of the months in the latter is arbitrary, and consists of entire days which facilitate the calculation.

The Indian solar calendar, compared with the Luni-Solar is very simple; and probably it is on this account that it has been

* The correct number for tithi is 22 610. See example of Section 82.

adopted by our brethren dwelling in the eastern and southern maritime provinces Undisturbed by adhika months, its dates are more in harmony with the seasons As the days begin at Sunrise invariably, there is not much ado about the fixing of the socio-religious holidays But the luni solar calendar, notwithstanding its inconveniences, is more phenomenal and attractive Coming from the north and west, it has pushed the solar calendar towards the southern and eastern shores, and has forced its way to the sea between Vizagapattana and the mouths of the Krishnâ.

110 The Indian solar months and dates may be classified under two heads, *viz* *The Bengal Orissa* and the *Tamil-Malayâlam* The former class exclusively follows the Surya Siddhânta and the latter the Ârya Siddhânta In the first class, the dates are quoted in the Bengali San and Vilâyati eras while in the latter class they are cited in Kaliyuga Shaka or Kollam eras.

111 The following is a list of *Solar Months* with their concurrent Rashis —

No	Rashis	Bengal Orissa S months	Tamil S months	Malayalam S months
1	Mesha	Vaishâkha	Chittirai	Medam
2	Vrisha	Jyestha	Vaikasi	Edawam
3	Mithuna	Âshadha	Ani	Mithunam
4	Karka	Shrâvana	Adi	Karkâtagam
5	Simha	Bhâdrapada	Avani	Chingam
6	Kanya	Âshvina	Purattasi	Kanni
7	Tula	Kârtika	Aipasi	Tulam
8	Vrishchika	Mârgashirsha	Kartikai	Vrischikam
9	Dhanu	Pausha	Margali	Dhanu
10	Makara	Mâgha	Tai	Makaram
11	Kumbha	Phâlguna	Masi	Kumbham
12	Mina	Chaitra	Panguni	Meenam

THE BENGAL ORISSA SOLAR DATES

(In the calculation use Tables 3, 4, 13)

112. The object of this, as well as of the next, section is to enable the student to convert any Indian Solar date into its corresponding Christian date

Method—If the citation of the date contains the year of the Bengal San, it must be changed into the corresponding A.D year by adding to it 593 years. (Table 1.)

With the A.D. year as argument, take down from Table 3 the 2nd and 3rd elements of the required century, and add to them their increase for odd years given in Table 4, and add them up, taking care to cast out thirties from the Tithi-shuddhi when it exceeds thirty.

Below the sums write the increase up to the given Sankrânti or month, as given in Table 13, and sum them up. Thus we get the elements for the moment when the Sun enters the given sign or Sankrânti. Here we should pause a little and determine the English date on the first day of the Sankrânti according to the following *Bengal usage.*

(*a*) If the decimal fraction of the Vâra of the Sankrânti be less than 0·750, add its complement to the Vâra as well as to the English date. But if the fraction exceeds 0·750, increase the complement by unity before adding up. The sums will show the weekday and the English date current on the *first day* of the Bengal solar month.

Then add the remaining days of the solar month to the Vâra and the date, and determine the English month and date with the help of Table 11.

(*b*) **The Orissa Usage**—In the case of Orissa where the Amâli and Vilayati eras are used, the decimal fraction of the Vâra of the Sankrânti should always be deducted from the Vâra

Example—Find out the A D year, month and date corresponding to the Bengal San 1317, Solar Mâgha, 28th date Here 1317 + 593 = A D 1910

Explanation	A D	Vara	A D date
Tab 3	1900	4 620	A 12·620
„ 4	8	3 070	0·070
„ 4	2	2 517	·517
Meshadi Tab 13 Mâgha,	1910	3 207	A 13·207
		2 637	275·637
Fraction 844 exceeds 750 Therefore add complement + 1		5 844	288·844
		1 156	1 156
On Magha 1 Add 27 to date and 6 to Vâra		0 000	290·
On Magha 28		6 000	27
Tab 11 April 0 to February 0		6	317·
			—306·
Eng date Friday 11th February 1910			11

Note—According to the usage of Orissa the date would be 9th February

The Tamil-Malayalam Solar Dates

(*In the calculation use Tables* 14 4 *and* 15)

113. The method of calculation is precisely the same as that of the preceding section Only we must make use of Tables 14 4 and 15, instead of Tables 3, 4 and 13 of the Bengal-Orissa dates and attend to the following usage as regards the determination of the date of the first day of the Solar month

The Tamil and Malabar usage—If the decimal fraction of the Vâra at the beginning of the Sankranti be less than ·500, the fraction should be deducted from the Vâra and the date But if the fraction exceeds 500, its complement should be added to Vâra and the date, to get the same i e, Vâra and date, on the first day of the solar month

The rest of the process is the same as before

Example—Find out the English year, month and date, corresponding to the Kollam Andu Era year 1086 (current), Dhanu 20th The Kollam year changes with Kanni after September 15 this case 1085 (expired) +, 825 = A D 1910 (Table I)

Explanation	A D	Vâra	A D date
Tab 14 4 4 15 Dhanu	1900 8 2	5 514 3 069 2 517 1 304	A 12 514 0 069 0 517 246 304
Fraction 404 is less than 500 By Malabar usage	1910	5 404 — 404	259 404 — 404
On Dhanu 1 Add 19 and 5 the change in Vâra		5 5	259 19
20 Tab 11 Apr 10 to January 0		3	278 275
Dhanu 20 = January 3rd	1911	Tuesday	3

The authors of the Indian Calendar state that the limiting fraction for the Malabar usage is 300 If this be the case the 20th of Dhanu would coincide with the 4th of January 1911

Note—Although the determination of the first day of a solar month is not uncertain when the local usage is known yet it would be well for the people who use the Solar Calendar to mention the week day of their dates like the Arabs who use the lunar Calendar months the first day of which is decided by the actual appearance of the thin crescent (See footnote to Section 132)

Problem—To convert an A D date into the solar one

114 The method of solving this problem is the reverse of that of the preceding sections 112 and 113

Change the century year of A D by means of Table 1 to its corresponding Bengal San or into Kollam year as the case may require

Find the Vara and the date for the Meshadi of the given A D year by using Tables 3 and 4 in the case of the *Bengal Orissa* dates and Tables 14 and 4 in the case of *Tamil Malabar* dates But when the date belongs to the month of January or February the Vara and the date for the Meshadi of the *preceding* A D year should be used

Find out by Table 11 the days elapsed from the beginning of the English month of Meshadi upto the given English

month and date and denote them by T Deduct from T the days of Meshadi and call the remainder R

Add to the date of Meshâdi the days in Table 13 or 15 under column (3) that are next to but less than R, and the sum will mark the beginning of the Solar month

Apply to the sum the correction of usage and determine the entire number of days on the first day of the solar month and deduct them from T and add 1 to the remainder The result will denote the current Solar date

Example —Calculate the solar date of the Bengal San corresponding to the 11th of February A D 1911

Here the A D date being in the month of February, we should calculate the date of Meshadi of the preceding year A D 1910

We deduce from Table 4 that the year A D 1900 corresponds to (1900 — 593) = 1307 of the Bengal San

Also by Table 11 the interval from April 0 to the 11th February is 317 which we denote by T Deducting the 13 days of April in the following calculation from 317 we get 304 for R

On referring to Table 13 we see that under column 3 the number of days next lower to 304 is 275 637 which being added to the days 13 207 of Meshadi gives 288 844 days from April 0 to the beginning of the Magha month Then adding 1 156 for Bengal usage we get 290 complete days for Mâgha 1

Expl nat	B S	A D	Vara	A D date
Tab 4 4 4	1307 8	1900 8 2	5 620 3 070 2 51	1? 6? 0 070 0 517
Meshâd 13 Days of Mâgl d < R less than R	1317	1910	4 ?0 ? 63	13 207 275 637
Mâghad Bengal usage			6 64 1 15	?88 844 1 156
Mâgha Tab 11 T	1		1 00	?90 000 317 000
	?7		6 00	?7
Mâgha	?8	date	000	sought

VERIFICATION OF DATES

THE TITHI

115 How the toil of computation can be minimised.— In the preceding Sections we have described the methods of accurate calculation which deserve to be employed in cases of exceptional importance. No epigraphist however zealous and energetic he may be will be found willing to undergo so much trouble in each case. A simpler and shorter method is no doubt necessary even though it be at the cost of a little accuracy which is not always necessary in the work of verification.

This is possible if we calculate a given tithi by means of the solar elements of Table 13 using only two decimal places in the computation and the Supplementary Table 5 where necessary.

We might also dispense with the nicety of adding the Sun's equation of centre to the Moon's anomaly, the omission of which will at the most produce a variation of one ghati in the ending moment of the tithi.

THE NAKSHATRA

The mean value of a nakshatra current with a tithi can also be very easily derived by the following short formula:

$$5{\cdot}8 + ({\cdot}9 \times \text{tithis}) + (\tfrac{1}{13} \times ☾\text{'s anomaly}^\circ)$$

116 We shall present below one or two models of working without lengthy explanations assuming that the reader has fully mastered the theory and reasoning of the foregoing calculations. (*Vide* Secs. 94–95.)

As a *first example* we shall test the accuracy and genuineness of the inscription at *Eran* which bears the date, Shaka year 406 Âshâdha Shukla 12, Thursday (*Vide* Section 94)

We should calculate here the elements for the Karka San kranti which is allied to Âshâdha

Explanation	Shaka	A D	Tithi	Vâra	A D date	☾ s anom	☉ s anom
Tables							
3	322	400	5 78	0 49	M 17 49	104° 2	250° 6
4	84	84	29 44	0 73	0 73	175 9	0 0
At Meshâdi	406	484	5 22	1 22	M 18 22	280 1	250 6
13			95 48	3 00	94 00	148 1	92 9
Karkâdi completion			100 70	4 22	112 22	68 2	13 5
			30	30	30	3 9	3
			101 00	4 52	112 52	72 1	13 8
5			1 00	0 98	0 98	12 9	1·0
Âshâdha Sh 12			102 00	5 50	113 50	85 0	14 8
				−0 05	−0 05		
				+ 41	+0 41		
Thursday				5 86	113 86	51 gh	36 pa
(1, March 0 to June 0					92 00		
English date					21	June	

Similarly by the preceding for nula

The Naksahtra $= 5\ 8 + (9 \times 12) + (075 \times 14\ 8)$

$= 5\ 8 + 10\ 8 + 1\ 1 = 17\ 7 =$ 18th or Jyestha

Example 2 —Verify the date Shaka 1106 on the day of *Shatabhishaja*, which was the 14th tithi of the first fortnight and *Wednesday* the 26th Solar day of the month of Simha

This inscription is cited in *Epigraphia Indica*, Supple ment to Vol VII p 132 as quoted by D B Pillai, Chronology p 74

Explanation	Shaka	A D	Tithi	Vara	A D date	O s anom
Tables 3 4	 1127 —16	 1200 —16	 7 64 27 04	 6 49 —6 14	 M 21 49 —0 14	 280 6 —0 0
Meshad 13	1106	1184	10 60 127 47	0 35 6 48	M 24 35 125 48	280 6 123
Simhâd Tamil usage			138 07 17	6 83 17	149 83 0 17	44 3 2
I of Simhaa 25 (by Tab 11)			138 24 25 40	0 00 4 00	150 00 25 00	44 5 25 0
26 of Simh Complement			163 64 36	4 00 36	175 00 36	69 5 0 4
Bhâdrapada 14 11 March 0 to August 0			164 00	4 36	175 36 153 00	69 9
The Mean tithi			ended	Wed	22 36	August

The Nakshatra = 5 8 + 12 6 + 5 2 = 23 6 Shatabhishaja current

Note —The inscription is therefore correct in all its citations

117 The Samvatsara cycle of 60 years—Origin —This 60 year cycle probably had its origin in the approximate coincidence of the periods of the Jovian and Saturnian revolutions round the Sun It is the smallest of the cosmic cycles at the end of which all the five planets assume very nearly the same geocentric configuration as they had at its beginning deviating on favourable occasions within six degrees one way or the other

Use —Formerly people remembered the name of Samvatsara of the year in which they were born and when asked how old they were they replied by stating the Samvatsara of their birth The Samvatsaras were also remembered as an aid to the memory of great calamities such as famines floods and epidemics for instance the great famine of *Ishvara Samvatsara* is named after it The cycle also coincides with the ordinary span of human life According to the Dharma Shastras a pious Hindu must perform the Shanti or penance on the completion of his 60th year

Viewed from the point of public utility it must be considered unwise to break its continuity as is done in Northern India by adopting in its place the *Jovian mean sign system* which necessitates the suppression of a Samvatsara in the course of 85 years The people of the Deccan have wisely adhered to the old custom of changing the Samvatsara regularly at the beginning of the year At present the northern cycle has advanced over the southern by 12 Samvats on account of the suppression

The cycle of 60 Samvatsaras seems to have been in use throughout India from remote antiquity Aryabhatta says that he was 23 years old when 60 cycles of 60 years from Kali yuga had expired *i e* in Kali 3600 This implies that the 60 year cycle has been in use without any interruption or suppression for 50 centuries We have shown in section 153 that the Indian and the Chinese 60 year cycles had probably a common origin

118 To calculate the Samvatsara in the 60-year cycle —Table 19 furnishes at a glance the Samvatsara current with a given A D year from the month of March to the end of December If the given year be of the Shaka Era it should be converted into that of the A D Era by adding 78 to it

The name of Samvatsara can also be found from table 19 when its index number is known

The following three formulæ will be found useful in determining the Samvatsara independently of the Table 19

$$\text{Samvatsara} = \text{Q (Kali years} + 13) - 60$$
$$= \text{Q (Shaka years} + 12) - 60$$
$$\text{Q (A D years} + 54) - 60$$

The symbol Q is used here in a new mathematical sense The lower stroke is supposed to signify the remainder left after the division In the above three formulæ the quantities within the brackets are to be divided by 60 and the remainder to be taken for the Samvatsara For instance the Samvatsara for Shaka year 1840 is 52 = Q (1840 + 12) — 60 *viz* the Kaliyukta (Table 19)

CHAPTER XI

The Jovian mean-sign cycle of 60 Samvats used in Northern India

119 Probable Origin —The mean sign cycle of Jupiter alluded to in the Surya Siddhânta appears to belong to the period of Samhitas which preceded by many centuries the introduction of the Siddhantas in India *But its re introduction into usage* on the new basis of exact calculation appears to be comparatively later This can be inferred from the fact that its commencement is quite abrupt in the list of Samvatsaras as it begins with *Vijaya* the 27th Samvatsara The choice of the first year Vijaya appears to be deliberate as it is meant to impress the minds of the followers with its meaning of *sure Victory* Bhaskaracharya defines the mean sign Samvatsara in the following manner —

वृहस्पतेर्मे यगराशिभोग सवत्सर साहितिका वदन्ति ॥

Here the word Samhitika appears to be used with the special object of pointing to its origin as much as to say that the intro duction of the mean sign system originated with the authors of Samhitas and not with an astronomer In our opinion the Jovian mean sign cycle serves no useful purpose but on the contrary it creates confusion and ambiguity in chronology not only by its two fold practices of being current either at the beginning of the year or at the date but also by the occasional suppression of years One should like to see it replaced by its elder Deccan sister (*Vide* Sec 117)

Problem —To find the Samvat current at Meshadi

(First Practice)

120 The problem can be solved by the help of the following formula —

Samvat = 18 005 + 1 0117 (A D years — 831)

Example —Find the Samvat current at the Meshadi *of* A D 1515

Putting the year 1515 in its place in the above formula and solving it we get—

Samvat = 18 005 + 1 0117 (1515—831)
= 18 005 + 1 0117 × 684
= 50 008 = The Subhanu in the list of Sec 122

But this same result can be obtained by mere addition by means of Table 20, which we have borrowed from D B Pillai's Chronology The theory of its construction will be found explained in Sec 121

Rule.—From Table 20, part A take down the element for the century of A D era add to it the increase for odd years from part B, and cast out sixties from the sum Refer the integers of the remainder to the list in Sec 122 and you will get the name of the Samvat current at Meshadi

Example—Find out the Samvat current at the Mesha Sankranti of A D years 1514 and 1515

EXPLANATION	A D	SAMVAT
Tab 20 part A Samvat for	1500	34 832
" B increase for	10	10 117
" B, increase for	4	4 047
48 Vrisha at Meshadi of	1514	48 996
B increase for	1	1 012
50, Subhanu at Meshadi of	1515	50 008

The Samvats for the A D years 1514 and 1515 are Vrisha and Subhanu respectively The Samvat 49 Chitrabhanu having no touch with either is suppressed like the Kshaya tithi or the Kshaya month This example illustrates the occasion when and the reason why it is necessary to *suppress* a Samvat

121. We will now give the theory of Table 20 which is prepared by mere continuous summation

Theory.—The length of a Samvat is the mean period in which Jupiter finishes one sign or 30 degrees It is therefore equal to one twelfth of its mean periodic time, and is 361 0267 days It is shorter than the sidereal year by 4 232 days The result of this defect is that in 85 308 years there occur 86 308 Samvats This superfluous Samvat is therefore to be suppressed like the tithi (Sec 35)

Samvat expired at Date Cited

(Second Practice)

123 In Northern India there is a second practice or mode of citing the Samvat which is expired not at the beginning of the year but at the date cited This mode is more reasonable than the first, because it requires *no suppression* of a Samvat This shows that thinkers soon after the innovation, realized the inconvenience and confusion arising out of the suppression They must have therefore followed this second mode in preference to the first But after all it was a bad innovation of a Samhitika meddling with the 60 year cycle of Samvatsaras which had been turning slowly and without jerks for many centuries The people of the Deccan were however shrewd enough not to be lured by it

Rule —When the first trial by Sec 120 fails to produce the cited Samvat we should calculate the interval from Meshadi to the date cited either in tithis or in days Then we should divide the interval in tithis by 367 or that in days by 361 and add the quotient to the Samvat of the Meshadi The result must agree with the citation Otherwise the citation may be considered to be faulty

Example —Verify the following date of a Sanskrit Manuscript given by its author as Shaka year 1396 Shubhakrit Kartika Shukla 9 Wednesday

Shaka 1396 *concurs with A D* 1474 *from the Meshadi*

Explanation	Shaka	Tithi	A D	Samvat	Vara
Tab 20 A			1400	53 662	
B			70	10 819	
B			4	4 047	
3	1322	0 610			6 242
4	72	16 667			6 630
4	2	22 130			2 517
At Meshâd	1396	9 407	1474	8 528	1 389
Tithi given T		219 000			
Interval in tithis	Tab 5	209 593	— 367 =	0 571	3 235
Samvat	Shubha	krit	at date	9 099	4 624

Here the Samvat obtained for Meshâdi is 8 528, *i e*, Plava (by the list in Sec 122) This does not agree with the author's citation So we obtained the interval between the Meshâdi and Kârtika Shukla 9, which is 209 593 tithis These divided by 367 give the quotient 0 571, which, when added to 8 528 amount to 9 099 The integer 9 when referred to the list in Section 122 indicates the Samvat Shubhakrit, which fully corroborates the author's citation made according to the second practice The week day was also Wednesday Table 5 yields 3 235 as increase in Vara for Arg 209 513

124. Name of the year in the 12 year Sub-cycle, as given in South India and Malayâlam.—There are two more practices of naming a year in Malabar and Travancore Their cycle is of 12 years and is based on the same principle. No separate calculation is, therefore, necessary, this cycle being itself a sub-cycle of the larger one

In the *third practice* the year is named after the name of the sign obtained as remainder, after dividing the number of the Samvats by 12 According to this rule, the year Shaka 1396, cited in the preceding section receives the name Makara Jupiter being then in the tenth sign (9 099)

This resembles the practice in the *Sankalpa* (*vide* sec 74), according to which one might say *Makarasthite De'agurau* But in the Sankalpa the position of Jupiter is geocentric and not the mean heliocentric as calculated above The difference, however, between the two positions of Jupiter never exceeds half a sign

125. The fourth practice —In this the names of signs are replaced by the names of those lunar months which derive their names from the nakshatras contained in those signs The year is called Kârtika when Jupiter is in Mesha or the first sign, and Mârga Shîrsha, when in Vrishabha or the second sign and so on with the prefix *Mahâ* to distinguish them from the ordinary lunar months

In the preceding example the year 1396 was according to the fourth practice of naming Mahâ Shravana There is a good reason for this peculiar nomenclature For, Jupiter occupying

the sign Makara rises and sets throughout the year called Mahâ-Shrâvana along with the nakshatra Shravana (the bright star Altair, Alpha Aquila *Vide* Fig 1). Thus Jupiter is made to act like a hand in a clock, pointing to the Jovian years recorded on the sky-dial

Example.—Let us verify the date of the following Malabar inscription by means of the mean position of Jupiter quoted in it "Kollam 389, Jupiter in Kumbha, and the Sun 18 days old in Mina"

before commencing the calculation These are the uncertainties that often beset the work of an epigraphist When he is confronted with ambiguities and discrepancies like these he must try every alternative before pronouncing any date as incorrect or impossible

D B Pillai in his chronology p 64 cites an amusing case, apparently unaccountable, in connection with the solar date of the birth of a Tamil gentleman born at Belgaum in the Bombay Presidency The date of birth in his horoscope was —

A D 1856 June 28 Ani 16

while in all the Tamil panchangams the English date corresponded to Ani 17 This apparent paradox baffled all conjectures till it was explained by the fact that the Tamil astrologer who cast the horoscope at Belgaum did not know that the panchangam which he used at Belgaum was calculated according to the Sûrya Siddhanta and not the Arya Siddhanta as he believed The difference was due to the difference in the times of Sankrântis that changed the first day of the Ani month and subsequent dates by one and the same Tamil usage sec 113 This will be shown below —

Surya S°	A D	Date	Ayra S°	A D	Date
Tab 3 4 13 Mithuna	1800 56	A 10 745 0 490 62 356	Tab 14 4 15 Ani	1800 56	A 10 646 0 490 62 376
	1856			1856	
Fraction greater than 500 Tamil usage		73 591 + 409	Less than 500 Tamil usage		73 462 — 462
Days from April 0 Tab 11 to June 0		74 61	From April 0 Tab 11 to June 0		73 61
Ani 1 15	June	13 15	Ani 1 16	June	12 16
Ani 16	June	28	Ani 17	June	28

Retrospect —Here we come to the end of our main object, *viz*, *the treatment of the mathematical part of Indian chronology*

We have done our best to render the subject clear both from the practical and the theoretical points of view But as no knowledge is rendered thorough and interesting without analogy and contrast we wish to acquaint our readers with the chronologies of other nations both modern and ancient

A short allegory —Time is Nature s ever increasing wealth and a free gift She bestows this favour without grudge or partiality on all nations and individuals both civilized and barbarous Chronology is the system of keeping the account of the receipts of these gifts of Nature, and History and Biography are the accounts of the daily and yearly debits The Calendars are the day books devoted to the entries of receipts only The days months years and cycles are the coins and currency notes signifying the gifts of Nature which are made on the condition that they are to be debited the moment they are received and the balance to be nil every moment

End of Part I

CHAPTER XII

127 **The Musulman Calendar** —The Calendar of the Musulmans is cyclic lunar Their Era which is called the *Hijra* commences on Friday the 16th July 622 A D and corresponds to the Hindu date Shravana Shukla 1 Shaka year 544 It commemorates the year of their Prophet s flight from Mecca which took place two months later in September in the month Rabi ul awwal

The natural unit of time common to the Musulman and the Christian calendars is the *mean solar day* while that common to the Musulman and the Hindu calendars is the *mean lunar month*

128 **The length of their lunar month** is 29 days 12 hours and 44 minutes exactly They are therefore made to consist of 30 and 29 days alternately as shown in the subjoined table making in all 354 days for an ordinary lunar year and 355 days for a leap year

Months	Days	Months	Days
1 Muharram	30	7 Rajab	30
2 Safar	29	8 Shaban	29
3 Rabi ul awwal	30	9 Ramzân	30
4 Rabi ul akhir *or* Rabi us sani	29	10 Shawwâl	29
5 Jumâdalâwal	30	11 Zilkâd	30
6 Jumâdalâkhir	29	12 Zilhijja	29
		Do (In a leap year)	30

129 The cycle of 30 years—The outstanding 44 minutes which amount to 11 days in 30 years are distributed over the 11 years of the cycle of 30 years in the following order, 2nd 5th, 7th 10th, 13th 16th 18th, 21st 24th, 26th and 29th This order of *leap years*, as they may be called by analogy, is adopted at Constantinople They are so chosen that by the addition of the leap day to the last date of Zilhijja, the time of the mean visibility of the Crescent occurs always within 12 hours either before or after the sunset of the new year s day

In some countries the years 8th 19th and 27th are considered as leap instead of the 7th 18th and 26th But this change breaks the desirable condition of 12 hours and so deserves to be abandoned

130 *The beginning of the day, month and year* —*Among* the Musulmans the day is reckoned from sunset to sunset The Moon is liked and respected more than the Sun This may probably be due to the fierce glare and the intolerable heat of the latter in the sandy deserts of Arabia

The month begins on the evening following the New Moon on which the faint and slender crescent is visible for the first time This rule though applicable in theory to all the months alike, is practically observed in the determination of the first date

of the Muharram and Ramzān months Our readers might have seen with what religous fervour the Musulmans watch from high places, on such occasions, the first appearance of the Moon's crescent and how joyfully they salaam each other at her first appearance

Monthly tithi = Hijri Tarikh + 2. . (a)
Hijri Tarikh = Monthly tithi — 2. . (b)

Spread as they are from Morocco in the west to the Malay Peninsula in the east, the Musulmans trust only to the testimony of their own eyes, and decide the first day of Muharram and Ramzân for themselves This is the reason why the Taboot day is sometimes celebrated on different days in different localities in India

To calculate the Christian date corresponding to a given Hijri one.

(TABLE 21)

133. Method.—Deduct 1 from the number of the Hijri year and divide the remaining years by 30 The quotient and the remainder will respectively be the *cycles* and the *odd years* expired.

(*a*) From Table 21, parts B and C, given under the Christian Era take down the increase for the cycles, years, months and days, and add them If the days in the sum exceed 365, divide them by 365, keep the remainder in the column for days and add the quotient to the years

(*b*) Divide the A D years thus obtained by 4, and deduct the integral quotient from the days as a correction due to leap years

(*c*) Add to the remainder the elements for the epoch in Part A The sum will represent the years, days and week days according to the *Old Style*

(*d*) Add 11, 12, 13 13, 14 and 15 days for the 17th, 18th, 19th, 20th, 21st and 22nd centuries respectively The result will be the year and days according to the *New Style*

Example—Required the A D year, month and date corresponding to the Hijri year 1337, Ramzan 1

Here 1337 — 1 = 1336 are the years elapsed, and dividing 1336 by 30 we get 44 cycles and 16 years

Type of calculation

	Explanation		Christian Era		
	Part	Table 21	Years	Days	Vâra
(*a*)	B Increase for 40 cycles		1165	15	4
	4 „		116	184	6
	C 16 years		15	195	0
	D Muharram 1 to Ramzan 1			236	5
			1296	630	15
	($630d = 1y$ 265 days)	Total	1297	265	1
(*b*)	Deduct leap days 1297 ÷ 4 =			—324	
	Total interval in Julian years and days		1296	306	1
(*c*)	A Epochal elements		622	196	6
	Sum date in old style		1919	137	0
(*d*)	Add for the 19th century			13	
	Sum date in new style		1919	150	0
	Days—January 1 to April 30 (by Table (*b*) of Sec 145)			—119	
	Result 1919 May 31st Saturday		1919	31	0

To calculate the Hijri date corresponding to a given Christian date

134 Method—(*a*) Deduct 621 from the given A D year, multiply the remainder by 365 and set down the product

(*b*) Divide the remainder by 4 take the integral quotient and write it below the product

(*c*) Also count the number of days from the beginning of the A D year not omitting the leap day of February if it intervenes, or use the table (B) in Sec 145

(*d*) Add up the numbers indicated by (*a*) (*b*) and (*c*) and deduct 561 days from the sum

(e) Then if the A D year be of the New Style deduct 11, 12 13 13 and 14 days for the 17th 18th 19th 20th and the 21st centuries respectively and call the remainder G But if the year be of the Old Style, nothing is to be deducted Thus G will be the number of days elapsed since the beginning of the Hijri Era, which we must now convert into Hijri years months and days

(f) From G deduct successively the highest possible number of days given in the columns headed Hijri Era in parts B C, and D of Table 21 Write down at the same time their respective equivalents in Hijri years and months The last remainder will be the day of the month

(g) Lastly add 1 to the number of years in order to change them into current year according to the Hijri Era

(h) The week day = Q (G + 6) — 7

Example.—Calculate the Hijri date corresponding to the 31st of May 1919 New Style

In this instance 1919 — 621 = 1298 are the intervening years.

		Days
(a) 1298 × 365		473 770
(b) 1298 — 4 = leap days		324
(c) January 1 to end of May 31		150
	Sum	474 244
(d) deduct the constant		— 561
(e) days to be suppressed for 19th century (New Style)		—13
G		473 670
(f) Deduct B 1200 years		— 425,240
		48 430
„ B 120		—42 524
		5 906
„ C 16		— 5 670
		236
„ D Muharram to end of Shâbân		235
(g) Add 1 year current 1337	Ramzan	1

Result —The corresponding date was Ramzan 1, 1337 the year of the Hijri Era

The week day = Q (473670 + 6) — 7 = 0 = Saturday

135 Mutual conversion of the Shaka and Hijri dates — Students of the Mughal and Maratha periods of Indian History often require to know the corresponding dates of these two Eras Table 22 is specially prepared for their use It shows at a glance the number of the Hijri month concurrent with the Chaitra of Shaka years 1369 2049

The Shaka years omitted in the table should be understood to begin with the Hijri month of the number attached to the preceding year For instance the omitted Shaka year 1370 begins with the Hijri month 1 *i e* Muharram the years 1372 1373 begin with the Hijri month 2 *i e* Safar and so on

Problem —To find the fractional number of Hijri year corresponding to the Meshadi of the given Shaka year

This can be solved by the following formula —

$$H - S - 518 + \frac{S - 1368}{32\ 54}$$

Here H stands for the Hijri year and S for the Shaka year The sign — means concurs with

Example —What fractional Hijri year which begins with Muharram corresponds to the moment of the Meshadi of the Shaka year 1841 Here putting the Shaka year 1841 in the above formula and solving it we get

$$H = 1841 - 518 + \frac{1841 - 1368}{32\ 54} = 1337\ 51$$

$= 1337$ years and 6 5 months completed at the moment of the Meshadi

This shows that the 7th month Rajab was running or was synchronous with the Chaitra of Shaka year 1841

This fact is also confirmed by Table 22

Now if it be desired to know what month of the Shaka year 1841 concurred with the Ramzân of the Hijri year 1337, we might show it thus—

Shaka				Hijri	
yr	m			yr.	m
1841	1	concurs with	.	1337	7
	2	add to each	. ..		2
1841	*3*	*Jyestha*	=	*1337*	*9 Ramzân.*

136. Problem 2.—Conversely to find the fractional number of the Shaka year corresponding to the New Moon of Muharram of the Hijri year.

This can be solved by the following formula

$$S = H + 518 - \frac{H - 850}{33\ 54}$$

Example—Suppose it is desired to know the Shaka year corresponding to the beginning of the Hijri year 1337

Proceeding as before—,

$$S = 1337 + 518 - \frac{1337 - 850}{33\ 54} = 1840\ 50$$

= 1840 Shaka year and 6 months which had elapsed at the beginning of Muharram

If we want to know what Hijri month was running with the Shaka month Jyestha

Shaka				Hijri	
yr	m			yr	m
1840	7	concurs with ..	..	1337	1
	8	add to each	.		8
1841	3	Jyestha	=	1337	9 Ramzân

Note—It may be noted that the above two formulæ are formed on the principle of *mean* intercalation while the concurrence shown in Table 22 is based on the actual calculation of the intercalary months This difference may occasionally produce a difference of a month, which can be corrected with the help of Table 2 or 22

137. The Arabic San or Sursan —The state papers and documents of the Maratha Period of Indian History always bear the years months and dates of the Arabic San coupled with Shaka months and tithis

The following formulæ show the relation between the Arabic, the Shaka and the Christian years

(*a*) Fasali year = Arabic year + 9

(*b*) Shaka year = Arabic year + 521 522

(*c*) A D year = Arabic year + 599 600

(*d*) Arabic year = Shaka year — 522 521

(*e*) Arabic year = A D year — 600 599

(*f*) Shaka year = A D year — 79 78

Note – We get two consecutive years from the above formulæ Of these the first concurs with the beginning and the second with the end of the given year in the second column

The Arabic San is Solar and like the Fasali year, begins at the moment when the Sun enters the Hindu *Mriga Nakshatra* It is on this account sometimes called the *Mriga Sal* Strange enough it has no months of its own and the defect is made up by the Lunar Hijri months current at date

Two formulæ must therefore be combined one for the year and the other for the month

138 Problem —Given any Shaka year to calculate the Arabic year and the Hijri month current at the moment of Mrigâdi which occurs in the Hindu month of Jyestha

(*i*) Arabic year = Shaka year – 522-521

(*ii*) Hijri month = The fraction of $\left(\frac{\text{Shaka years—1493}}{32\ 54}\right) \times 12$

Example 1 —Find the Arabic year and Hijri month and date at the moment of Mrigâdi in Shaka year 1842

As the Arabic year which began with Mrigâdi of the Shaka year 1842 was the latter one, we must make use of the latter number 521 in Formula (*e*).

The required Arabic year is $1842 - 521 = 1321$.

And by formula (H) of § 138

$$\frac{1842 - 1493}{32 \cdot 54} = 10 \cdot 725 \text{ of which—}$$

the fraction $\cdot 725 \times 12 = 8 \cdot 7$ months (Hijri).
$= 8$ months, 21 tithis.

By Sec. 132, Formula (*b*) $= 8$ months, 19 tarikhas.
$=$ 9th month Ramzân.
current at Mrigâdi.

Ans.—Arabic San 1321, Ramzân 19th tarikha.

139. The Arabic notation of years.—The Arabic years are often expressed in words, and very seldom in figures. The following words express the numerals which precede them :—

1	Ihide	8	Sammân	60	Sectain
2	Isanné	9	Tissâ	70	Sabbain
3	Sallâs	10	Ashar.	80	Sammâneen.
4	Arbâ	20	Ashareen	90	Tissain.
5	Khamas	30	Sallaseen	100	Mayyâ.
6	Seet	40	Arbain	200	Mayyâtain
7	Sabbâ	50	Khamsain	1000	Alaf.

Example 2.—Find the tithi, month and year of the Shaka Era corresponding to 14th tarikh of Rabi-ul-awwal of the Arabic or Sursan year Sallâseen, Mayyâ, and Alaf $= 30 + 100 + 1000 = 1130$. (Given in Art. 44, Part VI, Materials for the History of the Marathas by Râjwade.)

Arabic year $1130 + 521 = 1651$ Shaka, (Sec. 137)

On referring the Shaka year 1651 to Table 22 we find that the Chaitra corresponds to Ramzân the 9th, so that when counted from the Muharram of the preceding year, Rabi-ul-awwal is the 15th month, and the 14th tarikh corresponds to the 16th tithi.

Deducting 9 from these lunar months, we get 6 months and 16 tithis, and counting from Chaitra Shukla 1, we come to Ashvin Krishna 1 of the Shaka year 1651, which is the tithi sought

Example 3.—Find the Christian date, month and year corresponding to Jilkad 1 of the Arabic year Sammân, Sabbain Mayyâ, and Alaf = 8 + 70 + 100 + 1000 = 1178 (Given in Art 159 of letters etc collected in the Kâvyetihas Sangraha)

Arabic year 1178 + 599 = 1777 A D (Section 137) 1178 + 521 = 1699 Shaka (Sec 137)

On referring the Shaka year 1699 to Table 22 we find that the 3rd month Rabi ul awwal concurs with the Chaitra Deducting the 3rd month from Jilkad the 11th, we get 8 months and 1 + 2 = 3 tithis or 243 tithis in all Counting from Chaitra Shukla 1, we arrive at Margashirsha 3 We may now calculate the English date corresponding to Margashirsha 3 of Shaka year 1699 according to Sections (77—81)

Or we may calculate the approximate English date with Table 23, as shown below—

Explanation	Shaka	A D	Tithi	Date	Vâra
Table 23	1698	1776	-1 0	Ap 9 5	3 5
Table 23 bottom figures	1	1	11 1	0 3	1 3
At Meshâdi	1699	1777	- 1	9 8	4 8
Table 5 complement of 243			240 9	237 2	6 2
Mârgashir 3			243 0	247 0	4 0
Tab 11 April 0 to December 0				244 0	
Result Wednesday	1699	1777	Dec	3 0	4 0

CHAPTER XIII

THE CHRISTIAN CALENDAR

140 History of the Calendar.—We take the following description from Outlines of Astronomy ' by J F W Herschel — The history of the calendar, with reference to chronology or to

the calculations of ancient observations may be compared to that of a clock going regularly when left to itself but sometimes forgotten to be wound up and when wound sometimes set forward sometimes backward either to serve particular purposes and private interests or to rectify blunders in setting Such at least appears to have been the case with the *Roman Calendar* in which our own originates from the time of Numa to that of Julius Cæsar when the Lunar year of 13 months or 355 days was augmented at pleasure to correspond to the solar by which the seasons are determined by the arbitrary intercalation of the priests and the usurpations of the decemvirs and the magistrates till the confusion became inextricable To Julius Cæsar assisted by Sosigenes an eminent Alexandrian astronomer and mathematician we own the neat contrivance of the two years of 365 and 366 days and the insertion of one bissextile after three common years This important change took place in the 45th year before Christ which he ordered to commence on the 1st of January being the day of the New Moon immediately following the winter solstice of the year before We may judge of the state into which the reckoning of time had fallen by the fact that to introduce the new system it was necessary to enact that the previous year 46 B C should consist of 445 days a circumstance which obtained for it the epithet of *the year of confusion*

(*a*) But the real length of the tropical year is 365 24224 days and the yearly excess of about 00776 day amounted during the next four centuries to three days Consequently the equinox had retrograded from the 25th to the 21st of March At the *Council of Nice* in A D 325 it was enacted that the 21st of March should in future be the day of the *vernal equinox* but no remedy was suggested to check the ever accumulating error During the Popedom of Gregory XIII the equinoxial day owing to the unchecked excess actually fell on the 11th of March which was quite against the enactment of the Council of Nice The amount of the annual error being then correctly ascertained to be about three days in four centuries Pope Gregory XIII ordered that the 4th of October 1582 should be followed by the 15th of October and not by the 5th Consequently the equinox again fell on

the 21st of March in A D 1583 But the year 1582 consisted of 355 days only

(b) In order to secure the perpetual concurrence of the Vernal Equinox and the 21st of March the Pope further enacted that the century years that were not divisible by 400 without a remainder should be considered as ordinary years although they were divisible by 4 Thus the century year 1600 is a leap year but the years 1700 1800 and 1900 are not leap i e the number of days of February in these years is 28 The year 2000 will be a leap year and the years 2100 2200 and 2300 will be again ordinary years consisting of 365 days

This change is called the *New* or the *Gregorian Style* as distinguished from the Old or the Julian Style The New Style was at once adopted in all the Catholic countries But England hesitated till the year 1752 A D and finally adopted it by an Act of Parliament The 2nd day of September 1752 was the last day of the Old Style in England and the first day of the New Style was the 14th instead of the 3rd 11 nominal days being struck out

(c) The same legislative enactment which established the Gregorian year in England in 1752 shortened the preceding year 1751 by a full quarter Previous to that time the year was held to begin with the 25th March and the year A D 1751 did so accordingly but that year was not suffered to run out but was supplanted on the 1st January by the year 1752 which (as well as every subsequent year) it was enacted should commence on that day so that the English year 1751 was in effect an *annus confusionis* and consisted of only 282 days

Russia was the only country in Europe in which the Old Style was adhered to and (three secular years having elapsed) the difference between the European and Russian dates amounts to 13 days at present (A D 1920) But the Russian republic has now given up the Old Style

The change of calendar in England met with much popular opposition The day labourers complained that they were unjustly deprived of their wages for eleven days and the young ladies murmured that they were made older by the change

141. Astronomers are justly opposed to such sudden and abrupt changes in the calendar. Simon Newcomb says in his *Popular Astronomy* "*the length* of the mean *Gregorian* year is 365d 5h 49m 12s, while that of the tropical year, according to the best astronomical determination, is 365d 5h 48m 46s. The former is, therefore, still 26s too long, an error which will not amount to an entire day for more than 3,000 years. If there were any object in having the calendar and the astronomical year in exact coincidence, the Gregorian year would be accurate enough for all practical purposes during many centuries. In fact, however, it is difficult to show what practical object is to be attained by seeking for any such coincidence. It is important that summer and winter, seed time and harvest, shall occur at the same time of the year through several successive generations; but it is not of the slightest importance that they should occur at the same time *now* that they did 5,000 years *ago*, nor would it cause any difficulty to our descendants of 5,000 years hence if the equinox should occur in the middle of February, as would be the case, *should the* Julian Calendar have been continued.

The change of calendar met with much popular opposition, and it may hereafter be conceded that in this instance the commonsense of the people was more nearly right than the wisdom of the learned. An additional complication was introduced into the reckoning of time without any other real object than that of making Easter come at the right time."

142. The interval in days elapsed.—The chief object of chronology *is the* calculation *of the* exact *number of days, that* have elapsed since the Epoch of an era, or between any two given dates separated by a long interval. The Musulman calendar is better suited for this purpose. *It is not liable to any uncertainty* excepting the one due to the first visibility of the crescent moon after the New Moon. The error due to this cause would never *amount to more than a single day, and can be easily corrected* by the week-day if available. (*Vide* footnote to Sec. 132.)

Next to it in the matter of convenience are the Indian luni-solar and solar calendars. But the former is liable to an uncertainty *of a full month when the mean intercalary month is made*

use of in the calculation The solar calendar is the best as it is based on the number of days in a sidereal year and is not hampered by the Adhika and Kshaya months Yet the solar dates are sometimes rendered doubtful by the different usages in different parts of India as regards the determination of the first day of a month *Vide* Sections 112 113 and 126

143 The Julian Period —To avoid confusion in chronology the astronomers and chronologists have invented and adopted a new cycle of 7980 Julian years called *The Julian Period* It has been found so useful that the most competent authorities have declared that through its employment light and order were first introduced into chronology It was invented or revived by Joseph Scaliger who is said to have received it from the Greeks of Constantinople The first current year of the Julian period was 4713 B C and the noon of the 1st of January of this year for the meridian of Alexandria is the chronological epoch to which all historical eras are most readily and intelligibly referred by computing the number of integer days intervening between that epoch and the noon (for Alexandria) of the day The meridian of Alexandria is chosen as that to which Ptolemy refers the commencement of the era of Nabonassar the basis of all his calculations The number 7980 is obtained by the multiplication of the numbers 28 19 and 15 which are severally the Julian years in the Solar the Metonic and the Indictional cycles This cycle consists of years and days only and resembles the smaller cycles of the Grahalaghava and Ketaki which consist of 4016 and 6940 days respectively

144 The leap year how determined —To determine whether a given Christian year is leap or not proceed thus—

OLD STYLE

B C years —Deduct 1 divide by 4 and if no remainder be left it is a leap year

A D years —In England the Old Style had been in use upto the date September 2 (inclusive) 1752 A D So the A D

years preceding this date are leap, when they are divisible by 4 without remainder.

NEW STYLE

A. D. years.—The New Style came into force after the above date. It is exactly the same as the Old one, differing from it by a single exception, which is that century years which are not divisible by 400, although divisible by 4 without a remainder, are not leap years but common years, *i.e.*, the days of February in them are 28. For instance the years 1700, 1800, 1900, 2100 are common years.

Note.—A counter correction to this rule is proposed. It is that years divisible by 4000 ought to be considered as common years.

Because 4000 tropical years contain,	Days.
according to Newcomb $365 \cdot 2422^{d} \times 4000$	$= 1460969$
" Gregorian Reformation—	
$365 \times 4000 = 1460000$	
Leap days 970	
	$= 1460970$

To calculate the number of days elapsed since the Julian epoch, corresponding to any given date, old style

Find the number of the Julian years (J P) elapsed as above and multiply them by 365

Add to these the leap days obtained by adding 3 to the Julian years elapsed and dividing them by 4

Add also the number of days intervening between January 1 and the given date from Table (B) on p 100

Example —Find the interval in days between the commencement of the Julian Period and that of the Kali yuga February 18 3102 B C

Here the years elapsed are $4713 - 3102 = 1611$,

	Days elapsed
1611×365	588015
$(1611 + 3) \div 4$ = leap days	403
Days elapsed Jan 1 to Feb 18 Tab (*B*)	48
At the Epoch of the Kali yuga	588466

To find the same for any given date of the *New Style* proceed as above considering the date as a Julian date Then from the resulting days subtract as follows —

	Days
For any date (N S) before March 1 A D 1700	10
After Feb 28 1700 and before March 1 A D 1800	11
1800 1900	12
1900 2100	13

Examples 2 and 3 —Find the number of days elapsed of the Julian Period on Sept 1st B C 1193 and April 3 A D 1878 which are the Epochs of the Aryan and Ketaki Eras

Here the years elapsed are $4713 - 1193 = 3520$ and $4712 + 1878 = 6590$ upto the two Epochs respectively

Example 2

	Days elapsed
3520 x 365..	1284800
(3520 + 3) — 4 — leap days .. .	880
Jan 1st to Sept 1st, Table (B) p 100 ..	244
Epoch of the Aryan Era	1285924

Example 3

6590 x 365 = ...	2405350
(6590 + 3) — 4 = leap days	1,648
Jan. 1st to April 3rd, Table (B) p 100 ..	92
	2407090
Correction for New style	— 12
At the Epoch of Ketaki, see next page	2407078

To find the week-day of any Julian date.—Add 2 to the number of the days elapsed, and divide the sum by 7, and count the remaining days from Sunday as one. The result will be the week-day

In the above example adding 2 to 2407078 and dividing 2407080 by 7 we get 4 as remainder, and counting from Sunday we get Wednesday for the Epoch of Ketaki

By following the same course we get Friday for the Epoch of the Kali yuga

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Intervals in days between the commencement of the Julian Period and that of some other remarkable chronological and astronomical Epochs.

TABLE (A)

of important Epochs partially derived from J F W Herschel's Outlines of Astronomy

Names of Eras and Epochs	First day of Era	Chronology B C	Julian Period years	Interval in days elapsed
Julian Period	January 1	4713	1	
Kaliyuga (Era of the Deluge)	February 18	3102	1612	588 466
Epoch of Aryan Era*	September 1	1193	3521	1285974
Olympiads	July 1	776	3938	1438171
Era of Nabonassar	February 26	747	3967	1448639
Eclipse of Thales	May 28	585	4129	1507900
Metonic Cycle	July 15	432	4282	1563831
Julian Reformation	January 1	B C 45	4669	1704987
Dionysian Era	January 1	A D 1	4714	1721424
Hejira (New Moon)	July 15	622	5335	1948439
Era of Yezdgird	June 16	632	5345	1952063
Last day of old style	September 2	1752	6465	2361221
Epoch of Ketaki*	April 3	1878	6591	2407078

* See page 99

TABLE (B)

Days elapsed from Jan 1st to the 1st of each month

Months	In a common year	In a leap year	Months	In a common year	In a leap year
January 1			July 1	181	182
February 1	31	31	August 1	212	213
March 1	59	60	September 1	243	244
April 1	90	91	October 1	273	274
May 1	120	121	November 1	304	305
June 1	151	152	December 1	334	335

146 Perpetual Almanac for the European Calendar — The perpetual Almanac enables us to find the week day or Vara of any English date In fact it is a means of testing the accuracy of a date by casting out sevens in the same manner as we test the accuracy of a product by casting out nines It is given in several forms but here we have adopted that in which it is given by D B Pillai in his Chronology for the sake of its great simplicity See table 24

147 The Index-numbers —The numbers in heavy type printed at the tops of the columns of centuries years and months in Table 24 may be called the *Index numbers* They are common to all the numbers of years and months shown in the column below them The index number for the days of a month is the remainder left after dividing them by 7

148 To compute the week day of a given Christian date stated in A D years

Rule —All that we have to do is to add up the Index numbers of the four component elements of time *viz* the century year, month and date of the given day as shown in Table 24 and to cast out sevens from the total if it exceed 7 The remaining Index number will show the week-day beginning with Sunday as 1

Example —Required the week day on June 10 1858

By Sec. 144 the year 1858 is not leap

				Index
Table 24 the Index of A D		1800	century	4
,	,	58	years	2
,,	,,	6	June	3
,,	,,	10	days	3
	The required week-day is Thursday			5

149 Rule in the case of B C years —In calculating the week-day of a B C date the given B C year should be deducted from the last preceding century and the remainder should be used as odd year

Add to the Index of the last preceding century, the Index of the odd year thus found and that of the month and of the date as before

Example.—Required the week-day of 18, February 3102 B C, which was the first day of Kaliyuga

By Sec 144 Q(3102 — 1) — 4 = 1 It is therefore a common year

	Index
Table 24 Index of B C 3201 (the last preceding century)	3
(3201 — 3102) = 99 odd years	4
February in ordinary year	2
18 days of month	4
The Kaliyuga began on Friday	6

150 Theory of the formation of the perpetual calendar.—A century consists of 36525 days or 5218 weeks minus one day This is the reason why the B C centuries advance and the A D centuries recede along the Index numbers

An odd year when not leap, consists of 52 weeks plus one day This fact explains why the odd common years advance along the Index numbers

As the first year A D and the first date of January began at the same moment on Saturday the Index of which is zero (0) the zero date of January *i e* December 31 must have 6 for its Index

NOTES ON WEEK-DAYS

Use—The cycle of week days like the decimal notation has been adopted by every civilized nation It is to the illiterate what the cycle of Samvatsaras is to the educated A day is too short and a month is too long for common people to count and remember The market days, the payment of wages to the day labourers the recovery of interest for small money lending business the periods of the prescription of medicine and similar short terms and engagements are most conveniently regulated by means of the weeks

The week is a little calendar solely dependent on human memory, and incapable of being determined from observation of the heavens.

The origin of the week-days.—The origin must be ascribed rather to the astrologers than to the astronomers. For the order is governed by the supposition, or rather superstition, that each of the 24 hours of the day is ruled by the planets by turns, according to the descending order of their Periodic times, *viz.*, Saturn, Jupiter, Mars, the Sun, Venus, Mercury and the Moon, when written so as to complete a circle. It is plain then to see that if Saturn should preside over the first hour of a day, it will preside again over the 8th, 15th and 22nd hour, and then it will be the Sun's turn, occupying the third place in the cycle from Saturn to preside over the 25th, or the first hour of the second day, and the Moon's turn to preside will be on the first hour of the third day and so on.

The Sûrya Siddhânta briefly explains the above theory of the week-days in the following verse.

मन्दादधः क्रमेणस्युश्चतुर्था दिवसाधिपाः ॥ ७८ ॥
होरेशाः सूर्यतनयादधोऽधः क्रमशस्तथा ॥ ७९ ॥
(भूगोलाध्याय १२)

Meaning—From Saturn downwards every fourth in the (cyclic) order is the lord of the day. From Saturn downwards in due succession they are each the lords of the hours.

CHAPTER XIV

BRIEF NOTICES OF OTHER LUNI-SOLAR AND SOLAR CALENDARS

(1) The Vedic Calendar

151. The vedic Calendar is one of the most ancient, being compiled in the fourteenth century Before Christ. Each Veda had its own Jyotisha. The Rigveda Jyotisha consists of 36 verses and the Yâjusha Jyotisha of 43, of which 30 verses are common

to both. Most of them are very unintelligible. Messrs J. B. Modak, S. B. Dixit, B. G. Tilaka, Bârhaspatya and others have tried to interpret them in their own way. But there are still a few verses which have baffled all their attempts at explanation.

(a) Its primary object was to announce to the village cultivators the progress of the seasons and the fortnightly and other sacrifices were but a means to gain this chief object. The Agnihôtris, who were much esteemed and amply provided with corn and other necessaries, kept up a regular watch over the movements of the sun, observing the Equinoxial and Solstical days every year.

By this course the Agnihôtris soon came to know that the seasons happened regularly with respect to lunar months in the course of 5 years. Thus the Aryan Agnihotris established the five year cycle, which contained 60 solar months, 62 lunar months, 67 lunar revolutions, 1830 solar days, and 1860 tithis. They were also clever enough to mark that the Sun and the Moon turned towards the north after reaching the Dhanishthâ Nakshatra (Alpha Delphini).

(b) The first year of the opening cycle began with the New Moon which fell on the day of the winter Solstice. The chief object of the calculations was to determine the lunar tithis and months on which the bi-monthly seasons, the Equinoxes and the Solstices recurred in each of the five years, and as a course preparatory to determine the days (tithis) of the above phenomena, it was necessary to calculate at first the position of the Sun accurately with respect to the Nakshatra Divisions for each of the 124 New and Full moon days in the cycle. This is the same method of calculation which is followed in the preparation of the Nautical Almanacs, in which the positions of the Sun and the planets are calculated first, and the table of phenomena calculated with them is placed at the end.

The motions being mean, Mr. S. B. Dixit has embodied the preparatory course at pages 77 and 78 of his Marathi History of Astronomy, and the phenomena are stated at pages 91 and 75 as described in the Garga Samhitâ.

(c) In fact this little cycle of 5 years was far from being perfect For the defect of the lunar year as compared with the solar year is 11 tithis which amount to 55 tithis at the end of the fifth year By intercalating two lunar months we intercalate 5 tithis more than what is required In other words we add unnecessarily one tithi per annum and unless there is a provision to get rid of this excess the cycle must become useless after 30 years

But as we meet with references and allusions made about the cycle in the Mahabharata and its use in the Pitamaha Siddhanta which was in use in A D 80 there must have been a proviso for the removal of the undesirable excess in intercalation when it amounted to a whole month in 30 years by omitting the 12th intercalary month But unfortunately the verse containing the correction has somehow disappeared along with others from the text of the Vedanga We can however infer the existence of such a proviso in the following definition of the Âdiyuga i e the first cycle which fulfilled the original conditions of the Epoch after every 30 years

स्वराक्रमेते सोमार्कौ यदा साकं सवासवौ ।

स्यात् तदाऽऽदियुगं माघस्तपः शुक्लोऽयनं ह्युदक् ॥

(d) The presence of this correction is clearly traceable in the following verses in the Mahabharata —

तेषां कालातिरेकेण ज्योतिषां च व्यतिक्रमात्

पञ्चमे पञ्चमे वर्षे द्वौ मासावुपजायतः ॥ ३ ॥

एषामभ्यधिका मासाः पञ्च च द्वादश क्षपाः

त्रयोदशानां वर्षाणामिति मे वर्तते मतिः ॥ ४ ॥

पूर्वयुरेव निर्वृत्तास्ततो बीभत्सुरागतः

विराटपर्व अध्याय ५२

Here the word क्षपा is irrelevant to and irreconcilable with the meaning intended by the speaker Bhishma. There is no question at all about the nights I think that the word क्षपा was originally क्षया * but was mistaken by the scribe for we

* A copy (No. 4 2, Vishrama I foll 53) in Bhandarkar Research Institute actually reads —"पञ्च च द्वादश क्षया ॥ ५२ ४३ ॥ This copy makes full distinction between क्ष and ष

often meet with instances of प mistaken for य Also शश्व seems to be used for षयाश्व for the exigency of metre With this emendation the above verses state with astronomical accuracy that 13 solar years (s) are equal to 13 lunar years (l) plus 5 intercalary months minus 13 tithis This can be stated algebraically—

$$13\ s = 13\ l + 5 \text{ months} - 13 \text{ tithis}$$
$$30\ s = 30\ l + 12 \text{ months} - 30 \text{ tithis nearly}$$
$$= 30\ l + 11 \text{ months}$$

(*e*) The above demonstration clearly shows that the rule of omitting or suppressing every 12th intercalary month must have been in practice in the time of the Mahabharata This resembles the Gregorian rule in connection with the omission of leap days We sometimes meet with allusions to kshaya months in the age of cyclic calculations In such cases the kshaya months must be no other than the omitted intercalary months

The above rule can be also deduced from astronomical data

$$s = 371\ 05 \text{ tithis (page 210)}$$
$$\text{or } s = (360 + 12 - 1 + 0\ 05) \text{ tithis}$$
$$30\ s = 30\ (360 + 12 - 1 + 0\ 05) \text{ tithis}$$
$$= 30\ l + 12 \text{ months} - 1 \text{ month} + 1\ 5 \text{ tithis}$$
$$600\ s = 600\ l + 20\ l - 20 \text{ months} + 1 \text{ month}$$
$$= 600\ l + 221 \text{ intercalary months}$$

So I suggest that the following two verses composed by me may be read, in place of the missing ones immediately after the 37th verse of the Yajus Jyotisha beginning with यदूर्ध्वं दिनभागानां सदा पर्वणि पर्वणि By this means the Vedanga Jyotisha Cycle can be used for sacrificial purposes even at the present day, if its epoch is known which is probably B C 1440 = 1193 + 247 (*vide* sec 152)

विहाय युगपर्यन्ते ६ मासं माघं मलिम्लुचम्
प्रारभेत सदाऽऽद्यानि युगानि च पुनः पुनः ॥ ३८ ॥
न हेयः षट्शताब्दीयो ६०० माघमासोऽधिकस्तु यः
एवमादियुगारम्भो योग्यकाले सदा भवेत् ॥ ३९ ॥

(f) We shall finish this brief notice of the Vedânga Jyotisha by mentioning the fact that it has rendered the greatest service to the cause of *Indian antiquity* by recording the position of the Solsticial points in its time This has led to the fixing of its date as 1400 B C, and also of other dates of the Vedic literature relatively to it

Professors Max-Muller, Whitney and others have in vain tried to reduce this impregnable stronghold of Indian Antiquity (*vide* Max Muller's preface to the 4th volume of his Rigveda Samhitâ)

(g) It appears that the sage by name Lagadha was the original author of a small tract on the Vedic calendar and that the Vedânga Jyotisha was simply an adaptation of it as the following opening verse clearly shows .—

प्रणम्य शिरसा काल अभिवाद्य सरस्वतीम्

कालज्ञानं प्रवक्ष्यामि लगधस्य महात्मनः ॥

The title कालज्ञान literally means knowledge of time, the same as the French title 'Connaissance des temps' This shows how true ideas concur although the thinking minds may be separated by thousands of years

Calculations made on the basis of the greatest length of the day, stated by Lagadha, show that he lived in latitude 35 degrees North probably in Cashmere

(2) The ancient Indian or Aryan Calendar
(*In use from* 1193 *B C to* 291 *A D*)

152. To me it had been a great puzzle to understand how the ancient Indian kings could have managed their state affairs for centuries without a well-regulated calendar and an era for its basis until I saw the following table given by John Bentley in his Historical View of the Indian Astronomy Being given in a rudimentary form and without any directions regarding its use, the table has hitherto failed to attract the attention of scholars

But I found it fully practicable and therefore thought it worth while to recalculate it with a view to detect errors in it and to amplify it by placing alongside other concurrent Indian eras

Table showing the Ancient Aryan Tropical Solar Calendar

Cycles	Christian Chronology		Aryan Chronology				Siddhântic Chronology	
	B C	Mon Date Day	Year	Month solar	Sun	Spica	Kali	Shaka Mon tithi lunar
				long	long	long		
1	1193	Sept 1 Thurs 1283924 J P	0	Asvin ☾222°	150°	160	1909	—1270 Bhad 6
2	946	Oct 1 Satur 1376170 J P	247	Kârtik ☾252°	180	163⅓	2156	—1023 Âsvin 6
3	699	Oct 29 Sun 1466415 J P	494	Mârga ☾282°	210	166⅔	2403	—776 Kârtik 6
4	452	Nov 27 Tues 1556661 J P	741	Paush ☾312	240	170	2650	—529 Mârg 6
5	205	Dec. 25 Wed 1646906 J P	988	Magha ☾342	270	173⅓	2897	—282 Paush 6
6	A D 44	Jan 24 Fri 1737152 J P	1235	Phâlg ☾12	300	176⅔	3145	—34 Mâgh 6
7	291	Feb 21 Satur 1827397 J P	1482	Chaitr ☾42°	330	180	3392	+213 Phâlg 6 ended at 56 gh

Note—J P =Days of the Julian Period expired at Sunrise

(*a*) The opening tithi of the 1st cycle was called Âdikalpa shasthi that of the 2nd Guha shasthi that of the 3rd, Mitra saptami which we at present call Ratha Saptami

The following are the ancient constants and elements with which the above table is computed In a cycle —

Sun's tropical revolutions	$247\frac{1}{12}$	Mean solar days	90245 5
Moon's do	$3303\frac{1}{12}$	Lunar tithis	91680 0
solar months	2965	Precession seconds	12000 0
Lunar months	3056	Tithis in a solar month	30 9205
Intercalary months	91	Days do do	30 4368

The following ancient values are obtained from the preceding elements for comparison with the modern ones :—

	Ancient.				Modern.			
Length of—	Days	H.	M.	S.	Days	H.	M	S.
Tropical year ..	365	5	50	10	365	5	48	46
Sidereal year ..	365	6	9	53	365	6	9	9
Lunar month ..	29	12	44	3	29	12	44	3
Moon's revolution ..	27	7	43	5	27	7	43	5

	Days.	Days.
247 $\frac{1}{19}$ tropical years ..	90245·5	90245·26
3303$\frac{4}{19}$—Moon's trop. revolu.	90245·5	90245·723
Yearly precession ..	48″·567	50″·236

(*b*) This Aryan cycle of 247$\frac{1}{19}$ tropical years is really a happy combination of the lunar, solar, and sidereal systems. It contains 13 metonic cycles and one month. Each new cycle begins invariably on the 7th tithi of the month next to that with which the preceding cycle has begun. The precession of the equinoxes in one cycle amounts exactly to a quarter of a Nakshatra, and the 7th cycle begins in the year A.D. 291, in which the tropical longitude of the brilliant and conspicuous star Spica (Chitrâ) was exactly 180 degrees, as mentioned in the old Surya S°, quoted in the Pancha Siddhântikâ. [*Vide* sec. 200 (*a*).]

It completely fills up the hitherto supposed chronological gap of fifteen centuries, separating the Vedânga and the Siddhânta periods. This calendar must have been in general use while the five-year Vedic calendar was used only for sacrificial ceremonies But the cycle was not destined to run for ever. It appears probable that soon after the star Spica had coincided with the autumnal equinox, the Babylonian astronomy appeared in India and threw into the background the ancient Indian chronology. Learned men were willing to adopt it but the orthodox, as was natural, strongly opposed it. Thus the Romaka and Paulish works commented on by Lâtadeva were rejected as being अविग्रह i.e., opposed to the scriptures. The efforts of Shrishena and Vijayanandi shared the same fate.

(c) At last Âryanâtha* or his predecessor or some unknown contemporary astronomer realised, it appears, the necessity of gratifying the orthodox in the manner of children crying for the Moon He adopted in his Siddhânta the era of Kaliyuga and its colossal multiples, the Mahâyugas and the Kalpa Computing backward with the correct mean motions of the Sun and the moon from the Kali year 3600, he arrived at *Shukla saptami*, as the tithi of Mesha Sankrânti in the zero year of the Kaliyuga This result was very disappointing to him For he wanted an Amâvâsya or New Moon day to gratify the orthodox by presenting them with a general conjunction of the Sun the Moon and the planets Undaunted by the adverse result he made no scruple to carry back the origin of longitude itself seven degrees in order to show to the orthodox that the Mesha Sankranti did fall on the New Moon day according to their expectations To prevent this artifice from being detected it became necessary to distribute this increase of 7 days over 3600 years He accordingly raised the length of the sidereal year given in the foregoing table 365 days 6h 9m 53s = 365 days, 15gh, 24pa, 42 vip to 365 days 15 gh 31 pa 30 vip Thus the vitiated sidereal year was introduced for the first time and was implicitly followed by the subsequent astronomers without the least suspicion The equinox had receded three degrees behind Chitra in Shaka 421 and the arbitrary putting back of the starting point by seven (7) degrees raised the error to ten (10) degrees or days in the Zero year of the Kaliyuga This minus error of 10 days or 36000 palas is made good at the annual rate of 7 palas in about Kali 5000 years So now A D 1920 is the proper time for rejecting the vitiated year and for replacing it by its modern correct value 365d 15gh 23p adopting the time honoured starting point opposite to the star Chitrâ (Alpha Virginis)

The liberties taken by Âryanâtha with the positions of the planets in bringing about a perfect conjunction on the 17 18 of February 3102 B C are really appalling He has added empirically $+35°, +33°, +12° - 17°, +20°$ to the longitudes of the planets beginning with Mercury with corresponding changes in their mean motions and has intentionally observed silence in the matter

* The supposed author of the original Surya S° Aryabhatta was probably his pupil at Kusumapura For he says—आर्यभटस्त्विह निगदति कुसुमपुरेऽभ्यर्चितं ज्ञानम् ।

of the latitudes and longitudes of the yoga taras probably for fear of his artifice being detected from their observations

We shall now demonstrate below by making use of the data of our Jyotirganita how the sidereal year of the ancient Aryans was changed into that of the Surya Siddhanta —

Explanation	In Kali	Abdapa or Vara	Tithi Shuddhi
Time of the Sun s arrival— At the Equ nox of Shaka 218 Jyo p 64 In shaka year 1800 Spica—180	Year 4979	v gh pa 6 9 °8	 9 8°
Table 10 Change in years	4000 900 70 9	6 29 5° 3 44 13 3 56 46 4 18 26	29 66 26 17 24 37 9 56
Deduct from the top line the sum	*4979*	*4 °9 17*	*29 76*
At Equinox of Shaka 213 Sp ca — 180° Change for precession — 3°	0	1 40 11 —3 2 43	10 06 —3 10
At Equinox of Shaka 4°1 Spica — 183° Arb trary Set back for New Moon — 6 74	0	5 37 23 —6 48 12	6 96 —6 96
At Arb trary starting point Spica —189° 74	*0*	5 49 16	30 00

This arbitrary set back of 6 days 48 gh 12 palas made in the Abdapa for the sake of the New Moon of the preceding 3600 years amounts to 6 pa 48 vipalas per year and consequently

	days	gh.	pa	vip
The Aryan year (adopted by Ptolemy through the Chaldeans)	365	15	24	42
Arbitrary increase	+	.	6	48
The Surya S ddhânta year	365	15	31	30

(*d*) **Use** —This ancient Indian civil calendar being cycl c is fixed and does not stand in need of annual calculations Being also solar it is free from the uncertainty of the intercalary *months* In practical use it can be used as a safe guide in the determina tion of the dates of ancient events. As an instance of this we have determined in Sect on 201 the date of the Mahabhârata and the Bhagavadgîta within very close and precise limits

(e) Though entirely solar in character, the table also affords means of calculating the tithi and the nakshatra on a given day They can be calculated by means of the following formulæ

$$\text{Tithi} = 6 + 0\ 920742\ M$$

Where M is the period, in solar months, expired between the beginning of the cycle in which the given date is included and the end of the given solar month

Example 1 —Required the tithi on the day of the summer Solstice in B C 483 This day marks the end of the third solar month

The given date lies in the 3rd cycle, therefore

$M = (699 \text{ years} - 7 \text{ months}) - (483 \text{ years} - 3 \text{ months})$
$= (698 \text{ years} + 5 \text{ months}) - (482 \text{ years} + 9 \text{ months})$
$= (215 \text{ years} + 8 \text{ months}) = 2588$ solar months

And the required

$\text{Tithi} = 6 + (0\ 920742 \times 2588) = 18\ 88 = 19$ nearly

This means that the festival Vâssa of the Buddhists or the 'Fete de Soleil of the French astronomers was held in B C 483 on the Sankashti day (*Vide* Sec 99) where this same tithi is 18 3 as worked by the Surya Siddhanta elements

The Nakshatra (N) can similarly be obtained by the following formula—

$N = 13\ 5 + (0\ 9 \times \text{tithi}) + \frac{1}{40}\ (\text{Sun}^\circ - \text{Spica}^\circ)$

On the day of the summer Solstice in B C 483 for example

$N = 13\ 5 + (0\ 9 \times 19) + \frac{1}{40}\ (90^\circ - 170^\circ)$
$= 13\ 5 + 17 + 2 = 51\ 5 =$ Pûrvâ Bhâdrapadâ

Note — In order that the solar months may coincide with the English calendar months without affecting the years it is safer to add 90 degrees to the Sun s longitude in col 6 of the table, and then to divide the sum by 30° The quotient will correctly express the calendar months Or solar months may be counted from April as one

Example 2 —Find the tithi on which the era of Nabonassar commenced it being known that the years in it begin when the Sun s longitude is 330 degrees It commenced on February

26, 747 B. C. in the second cycle, which began with the Sun's longitude 180°. We must take it as 270° and the solar month as the 9th for the above reason.

As before,

$$M = (946\text{ y} - 9\text{ m}) - (747\text{ y} - 2\text{ m})$$
$$= (945\text{ y} + 3\text{ m}) - (746\text{ y} + 10\text{ m})$$
$$= (198\text{ y} + 5\text{ m}) = 2381 \text{ solar months}$$

And the required

Tithi = $6 + (\cdot 92 \times 2381) = 6 \cdot 52$, Saptami.

(*f*) *Important note*—This calculation discloses the important fact that the Chaldean and the Egyptian Era of Nabonassar and the Indian Aryan Era began on a Saptami. Not only this but even the length of the sidereal year is the same in both the Eras. This cannot be accidental, and as the Indian Era precedes the Chaldean Era by more than four centuries, the Chaldeans must have in all probability borrowed from the Indian Aryans their Era and Chronology. After making use of it as a basis for their astronomical pursuits the Chaldeans have returned the debt to us in the form of their astronomy. Though it is not proper to indulge in mere speculations, yet I cannot forbear saying that an important truth lies hidden in the word Chaldean, for it seems closely allied to the Sanskrit word कालद. Nay the Chaldeans themselves seem to have been a colony of the Indian Aryans calling themselves Caldais, *i e*, Time-givers or Chronologers. There is historical evidence to show (see Chambers' Ancient History) that the Chaldeans, though much respected for their learning, were looked upon as foreigners in Mesopotamia. They might also have carried with them from India the memory (स्मृति) of the general conjunction of the planets that took place in B. C. 3102, and of the imaginary vast cyclic periods of 432000 years (*vide* Sec. 209).

(g) On page 273 of "Histoire Abrégée de L' Astronomie par E. Lebon, 1899" we read the following description about the Chaldeans: " Les Chaldéens ont précédé toutes les autres nations pour les observations astronomiques. D'apres Diodore de Sicile, ils comptaient 432000 années d' observations astronomiques que

Berose reduit à 150000 ! Ces nombres sont de nulle valeur en histoire, cependent ils montrent la grande antiquite de ces observations La date terminale de la Chaldee 538 av J C, est l année de la prise de Babylone par Cyrus

Mr R Shama Shastri of Mysore has very ably proved in his Gavâmayana the relation between the Vedic word नराशंसस्वर (Narashamsaswara) representing 43200 syllables and the Chaldean words nerus, sosus and sarus for the cycles of 600 60 and 3600 years respectively His book contains reliable and very interesting information regarding the dim antiquity of the Vedic times

(3) THE CHINESE CALENDAR

153. The Chinese calendar is luni solar the months being lunar and the years tropical It is not based on any cycle but is computed like ours by means of the true positions of the Sun and the Moon Their era commences in the year B C 2637, and is reckoned in cycles of 60 years like our Deccan Samvatsara Chakra In the year A D 1919 seventy five of such cycles had elapsed and the 56th year of the seventy-sixth cycle was current The samvatsara in the Deccan in A D 1919 was the 53rd called Siddhârthî This near approach of the numbers of the years in the cycle suggests the probability of a common origin of the Indian and Chinese chronology at some remote time

The year begins in that lunar month in which the Sun s tropical longitude is 330° At present the first month concurs with the Hindu lunar month of Mâgha The months are indicated by the ordinal numbers like the Hindu Tithis and not by the sidereal names like Chaitra, Vaishâkha, etc. The Adhika or the intercalary month bears the same number as that of the proper one Their week days are 60, and have the same names as the years have in the 60 year cycle The day begins at midnight and is divided into 12 equal parts Their almanacs are prepared from tables constructed in the year A. D 1644 by Imperial order, But since the establishment of the Chinese Republic changes consistent with the calculations of the French Connaissance des Temps are said to have been introduced into them

THE SAYANAVADIS

Note.—The Chinese Calendar is a true Sâyana Calendar. The Indian Sâyanavâdis should, if they like, adopt it and stop in future their advocacy for giving the sidereal names to their lunar months and to their tropical 27 divisions of the Ecliptic. Seeing that the 12 zodiacal constellations no longer coincide with the 12 signs, European astronomers have long since abandoned the custom of stating the longitudes in signs, and have adopted in its place that of mentioning them in degrees (0 — 360). The constellations are only shown with vague boundaries in their star-atlases and are used in giving names to fixed stars.

The 27 nakshatras are the pure Indian zodiacal constellations used long before the adoption of the Assyrian 12 constellations. To name after them the 27 moveable (tropical) divisions of the ecliptic from the vernal equinox is, not only inconsistent, but productive of great confusion in future ages. There is no objection if the Sâyanavâdis name their 27 divisions by the ordinal numbers just as the Chinese do their months. The word Sâyan-Nakshatra is in itself ludicrously inconsistent, as it literally means a moving-stationary division. Modern astronomers have, it appears, omitted the old word 'sign' in their tables in order to avoid this very objection.

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(4) THE JEWISH CALENDAR

154. The calendar of the Jews is luni-solar and is regulated by a cycle of 19 years, called the Metonic cycle. Its months are lunar. The year contains 12 lunar months when it is common, and 13 months when embolismic. The years 3rd, 6th, 8th, 11th, 14th, 17th and the 19th in the cycle are embolismic or adhika. The order is nearly the same as that of the adhika years in Table 2. Deduct 1 from the years given in line 1 of it, and you obtain the above figures. *But there can arise no Kshaya months in a cyclic* reckoning. It is produced only when the names of Lunar months are determined with reference to the Solar months. (Sec. 65.)

155. The names of months are of Assyrian origin. These are—1 Tisseri, 2 Heswan, 3 Kisler, 4 Tibeth, 5 Schebat, 6 Adar, 7 Ve'adar

(adhika), 8 Nissan, 9 Iyar, 10 Sewan, 11 Tamouz, 12 Ab, and 13 Elloul.

Like the Vedâng Jyotisha the intercalary month Ve'adar is placed in the middle of the embolismic year. The first month usually concurs with the Hindu Âshvina. The day begins at sunset as in the Musulman calendar. The year is not permitted to begin on a Wednesday, Friday or Sunday, but on the day following, as they are considered unlucky.

The Jewish Calendar was recast into its present form in the fourth century A. D

(5) THE ECCLESIASTICAL OR CHURCH CALENDAR

156. Easter is the only religious festival, says Prof. Newcomb, which in Christian countries depends directly upon the motion of the Moon. The rule for determining Easter is that it is the Sunday following the first full Moon, which occurs on or after the 21st of March. The Church calculations of Easter Sunday are, however, founded upon very old tables of the Moon, so that if we fix it by the actual positions of the Moon, we should often find the Calendar feast a week in error.

"The natural units of time," says C A. Young in his Manual of Astronomy, "are the day, month, and year. The day is too short for convenience in dealing with considerable periods, such as the life of man for instance, and the same is true even of the month, so that for all chronological purposes the tropical-year—the year of the seasons—has always been employed. At the same time, so many religious ideas and observations have been connected with the changes of the Moon that, there was a long constant struggle to reconcile the month with the year. Since the two are incommensurable, no really satisfactory solution is possible, and the modern calendar of civilized nations entirely disregards the Moon."

Use of the Golden number and of the Dominical letter

The Golden number and the Epact at the beginning of a year are useful in fixing the date of the Paschal full moon, and the Dominical letter serves to show the Sunday dates. The French

Annuaire for A D 1919 contains two tables which give the Easter days from A D 1600 to 2200, both according to the Old and the New Styles

157. Easter can be calculated by means of our tables also At present the Meshadi occurs on the 12th of April. So the Easter full moon occurs between March (21—31) when the tithi-Shuddhi lies between 27 and 7, and between April (1—20) when it lies between 7 and 27 The date of Meshadi increases by 1 in 60 years, so the limits of the tithi Shuddhi will have to be raised by one when the Meshadi will occur on the 13th of April

Rule—Calculate the mean elements for the Meshâdi of the given A D year according to Sec 77 and complete the tithi Shuddhi or Epact as it is called, by Sec 78 Then deduct algebraically the completed tithi from 15, find out from Table 5 the motions of the elements for the remaining tithis and add them, according to the sign of the remaining tithis to the elements of the Epact

Calculate the ending moment by Sec 79-81. Then the date of the Sunday, next to the full-moon will be that of *Easter Sunday* and the preceding Friday will be Good Friday If the full moon falls on a Sunday, Easter day is the Sunday after

Example—Determine the date and the week-day of the Easter full moon in A D 1920

Type of Calculation for Easter day

Explanation	A D	Tithi	Vâra	Date	☾ s anom	☉ s anom
Tab 3	1900	13 027	5 620	A 12 620	7° 4	280° 6
,, 4	20	11 297	4 175	0 175	41 9	0 0
At Meshâdi	1920	24 324	2 795	A 12 795	49 3	280 6
Complement		0 676	0 666	0 666	8 7	0 7
S		25'	3 461	A 13 461	58 0	281 3
Tab 5 R	minus	10	2 844	9 844	128 6	9 7
T		15	0 617	A 3 617	289 4	271 6

Here Easter Full Moon falls on Saturday the 3rd of April Easter, therefore, occurred on the 4th of April 1920

(6) THE COPTIC CALENDAR OF EGYPT

158 This calendar is used in parts of Egypt and Ethiopia Like the calendar of the Parsis the year consists of 12 months, each containing 30 days with 5 intercalary days called *Epagomenes* added at the end of the twelfth month After three such years of 365 days in succession the fourth year has 6 epagomen days added at the end Thus it will be seen that the length of the Coptic year and the intercalation are the same as in the Julian Calendar

The intercalary or leap years of the Coptic calendar are those next preceding the Julian bissextile years. See Sec 144 Old style.

The era followed is that of the Diocletian or of the Martyrs, the origin of which is fixed on Friday 29th August 284 A D

Concordance of the Julian and Gregorian dates with the first day of each Coptic month in a common year (1637)

No	1637 Coptic months and their durat on in days 2nd common year		1920 Julian dates and months	1920 Gregorian dates and months
1	Tut 1 days	30	29 August	11 September
2	Bobeh 1	30	28 September	11 October
3	Hatur 1	30	28 October	10 November
4	Koyhak 1	30	27 November	10 December
5	Tubeh 1	30	27 December	1921 9 January
6	Amchir 1	30	1921 26 January	8 February
7	Barmahat 1	30	25 February	10 March
8	Barmudeh 1	30	27 March	9 April
9	Bachones 1	30	26 April	9 May
10	Bawne 1	30	26 May	8 June
11	Abib 1	30	25 June	8 July
12	Mesori 1	30	25 July	7 August
	Epagomenes	5	24 August	6 September
1	Tut 1 1638	365	29 August	11 September

An intercalary Coptic year ends on the 29th of August instead of the 28th ; and the next Coptic common year, having to concur partly with a Julian bissextile year, ends on the 28th August of the bissextile year. The second common Coptic year again commences on the 29th August of the Julian year. The formula of Coptic Leap Year (C) is : Q (C + 1) ÷ 4 = 0.

The excess of the Gregorian dates over those of the Julian is at present (A. D. 1920) 13 days. It will be 14 days on the 29th date of February of the Julian calendar in A. D. 2100, and 15 days in A.D. 2200. (The above information about the Coptic calendar is derived from the French Annuaire for A. D. 1920.)

CHAPTER XV

ECLIPSES

Importance—Eclipses, when they are mentioned in inscriptions and copper plates, are an unerring means of verifying their dates. The Hindu Scriptures affirm that the merit of a gift, made on the occasion of an eclipse, is great and permanent. It was mainly owing to this religious faith that the kings and princes of India made free grants of lands and even of villages to deserving Brahmins on the occasion of important eclipses.

159. Possibility and recurrence.—A lunar eclipse can occur only at the time of Full Moon, and a solar eclipse only at the time of New Moon, if the Sun happen to be near enough to one of the nodes of the lunar orbit (*vide* Sec. 55). The Moon is eclipsed by the earth's shadow, and the sun is eclipsed by the dark opaque body of the Moon passing like a cloud between a spectator on the earth and the sun. The interval between two successive eclipses is generally six months and sometimes a fortnight.

160. The Saros—The cycle of the eclipses is called '*Saros*, a word probably allied to 'Saura' by which name the celebrated Sûrya Siddhânta is sometimes cited. It was known to the ancient Chaldeans who used it to predict eclipses. It consists of 223 lunations, or 18 years and 10 or 11 days. In this interval there occur 71 eclipses of which 43 are of the sun and 28 of the moon. Though

the number of the Sun's eclipses is larger, their visibility in respect to a given place on the earth is much limited by the fact that the earth's surface traversed by the moon's penumbra is much smaller than that of the earth's hemisphere. It may sometimes happen that a partial solar eclipse actually seen in the Panjab may not be seen at all in the Madras Presidency and *vice versa*.

161 Our object in including the subject of eclipses in this book is not only to enable our readers to become acquainted with the calculation of one of the most interesting and awe inspiring phenomena but to show the great merit of the Surya Siddhânta that has turned, as it were, the two luminaries into its most obedient servants during the past 50 centuries. Besides our readers will be able to verify doubtful cases of eclipses independently of the list supplied to them by others (Sec. 218.) Also there are very few books in India on this subject accessible to the English knowing readers, so that they will find this subject a good pastime to enjoy when an eclipse is approaching.

THE ECLIPSE OF THE MOON

162 Method of calculation.—Take down from Table 3 the first 7 elements for the last preceding century of the given date and go through all the successive steps as described in Secs 77—80 till you obtain the ending moment of the true full moon tithi.

If the date be modern the empirical corrections of the Vara date, and moon's anomaly viz + 0.014 day + 0.014 day and + 3° 33 respectively must also be added after the increase for odd years (Sec 101.)

Example.—Calculate the lunar eclipse that took place on the 15th tithi of Chaitra Shaka year 1806 corresponding to 10th April 1884.

Note.—This eclipse is noteworthy for the fact that it was calculated with the elements of Grahalaghava and was found to be invisible at Bagalkot. Great was the surprise and chagrin of the pious and orthodox people when they beheld the moon rise with her upper border immersed in the earth's shadow, lasting over a ghati

Type of calculation

Tables.	A D	Tithi	Vara	Date	☾ s An	☉ s An	Rāhu
3 24 4 Corr	1800 84	16 543 29 445	5 745 0 735 0 014	A 10 745 0 735 0 014	157 94 175 93 3 33	280° 60 0 00	70° 8 185 64
Meshadi Complement	1884	15 988 — 988	6 494 — 9 3	A 11 494 — 973	337 20 —12 65	280 60 — 97	256 5
S		15	5 521	A 10 521	324 55	279 63	256 5
6 Arg	279 6	☉ eq	+ 176	+ 176	+2 11	=+ 176	× 13 =
7 Arg	326 7	☾ eq	— 245	— 245	326 66		2 11
Full Moon		0	5 457	A 10 457	Thurs	27 gh	7 pal

The above calculation shows that the Full Moon of Chaitra fell on 10th April 1884 at 27 gh 7 palas after the mean sunrise of Ujjain

163 Then calculate D which denotes the distance of the sun from the node Rahu according to the following formula and add 180° to it when the eclipse is a lunar one

D = + Rahu

+ ☉ s anomaly

+ ☉ s equation × 13

+ ☾ s equation

+ 02° (k—50) = Empirical correction.

k = Centuries of Kaliyuga.

Example—

D = 256 53 = Rahu

+ 279 63 = Sun s anomaly

+ 2 29 = ☉ s eqn × 13 = + 176 × 13

— 0 25 = ☾ s eqn

+ 0 00 = 02 (50—50) = Empirical correction

+ 180 00 To be added the eclipse being lunar

358° 20

164 With the value of D thus obtained, we are able *to decide* from the following limits whether a lunar eclipse will happen.

Lunar ecliptic limits.

	Doubtful	Certain or	Doubtful
A lunar eclipse is ..			
If D is between	347°—350°	350°— 10°	10°— 13°
or D is between	167°—170°	170°—190°	190°—193°

In the above example D is 358°·20 and lies between the limits 350° — 10° of certainty. We are, therefore, able to assert that there *shall* be an eclipse of the moon on the day in question. But the question in respect of its visibility must be postponed till we calculate the times of the moon's first and last contacts with the earth's shadow. If either of these times falls that day, after sunset and before the next sunrise, the lunar eclipse is sure to be seen.

165 Next find out the values of the elements *v*, *a*, *b*, *l*, *p*, and *t* as shown below—

From Table.	With Argument	Take out.	Which is the —
25	☾'s anomaly,	. *v*	= Moon's true daily motion.
26	*v*	. *a*	= Sum of semi-diameters of the moon and earth's shadow
26	*v*	.. *b*	= Difference of the semi-diameters.
27	D	. *l*	= Moon's latitude.
28	(*a*—*l*), *a*,	.. *p*	= Semi-duration of the eclipse
35	(*b*—*l*), *b*,	. *t*	= Do. of the total phase

Note.—In a lunar eclipse *l* should always be considered plus in finding out *p* and *t* from tables 28 and 35.

Example.—Thus :—

From Table	With Argument		We get		
25 ..	.. 326°·66	..	*v*	= 736′	minutes.
26 ..	.. 736′	..	*a*	= 55	,,
26 ..	.. 736′	..	*b*	= 24	,,
27 ..	.. 358°·20	..	*l*	= —10	,,
28 .	.. 45′ and 55′	..	*p*	= 282	palas.
35 ..	.. 14′ and 24′	..	*t*	= 116	palas.

166. The time of the Full Moon is not the time of the middle of the eclipse (m). The difference between these times depends upon D, and never exceeds 26 palas or about 10 minutes which can be ignored except when great accuracy is desired, in which case it may be found out in the following manner.

Deduct D algebraically from either 180° or 360° whichever be nearer to D. Then double the difference in degrees which will be the correction (*c*) in palas to be made to (*f*), the time of Full Moon, as shewn in the preceding type of calculation.

$$\text{So, } (f + c) = (m)$$

In the above example D is 358°·20, and 360° being *nearer to* it, 360° — 358°·2 = + 1°·8. The double of + 1·8 is + 4 which is the correction (c) in palas. This being plus, 27 gh. 7 pa. + 4 pa. or 27 gh. 12 pa. is the time of the *middle of the eclipse*. (m)

167. The times of the *different phases* can afterwards be determined with the aid of the following formulæ.

(m — *p*) = beginning of the eclipse.
(m — *t*) = beginning of the total phase.
(m + o) = middle of the eclipse.
(m + *t*) = end of the total phase.
(m + *p*) = end of the eclipse.
(*a* — *l*) = magnitude of the eclipse.
(*b* — *l*) = *Khagrâsa, i.e.,* covering of the sky, or extent of shadow beyond the moon's disc.

The *magnitude* is usually expressed in digits. A digit is equal to 2·5 minutes of arc. The calculation of the different phases by the above formulæ is shown below.

Lunar Eclipse. April 10, 1884. Ujjain mean time.

<table>
<tr><th colspan="2">Eclipse begins. m — p</th><th colspan="2">Totality begins. m — t</th><th colspan="2">Mid eclipse. m + o</th><th colspan="2">Totality ends. m + t</th><th colspan="2">Eclipse ends. m + p</th></tr>
<tr><td>gh.</td><td>pa.</td><td>gh</td><td>pa.</td><td>gh.</td><td>pa.</td><td>gh.</td><td>pa.</td><td>gh.</td><td>pa.</td></tr>
<tr><td>27
— 4</td><td>12
42</td><td>27
— 1</td><td>12
50</td><td>27
..</td><td>12
..</td><td>27
+ 1</td><td>12
56</td><td>27
+ 4</td><td>12
42</td></tr>
<tr><td>22</td><td>30</td><td>23</td><td>16</td><td>27</td><td>12</td><td>29</td><td>8</td><td>31</td><td>54</td></tr>
</table>

(*a* — *l*) = (55 — 10) = 45′ or 18·0 digits of magnitude.
(*b* — *l*) = (24 — 10) = 14′ or 5·6 digits of Khagrâsa.

168 The points of contact on the disc—The first contact with shadow in a lunar eclipse takes place on the eastern border of the moon s disc and the last contact on the western border In the Solar eclipse the opposite of this takes place

ANCIENT ECLIPSES

169 The most ancient lunar eclipse of 8th March B C 720.—This eclipse has been cited by Ptolemy as having been observed at Babylon in the latter half of the night the magnitude being three digits This we will calculate below, to show to the readers that the highest praise and almost religious regard paid in India to the Surya Siddhanta is not undeserved The longitude of Babylon from Ujjain is 31° 3 West or — 09 day and the latitude 32° 5 North The indefiniteness of the time says Newcomb renders the eclipse of very little value (Researches on the motion of the Moon, page 36) According to his calculation the time of the greatest phase at Ujjain is 3 A M

Model of calculation

Explanation	B C	Tithi	Vara	Date	☾ s anom	○ s anom	—Rahu
Tab 3	—801	17 98	1 98	M 6 98	110 9	280 6	138 9
4	80	15 19	2 70	0 70	167 6	0 0	108 2
4	1	11 06	1 26	0 26	92 1	0 0	19 3
Chaitra	—720	14 23	5 94	M 7 94	10 6	280 6	66 4
Longi of Babylon			— 09	— 09			
Meshâdi		14 23	5 85	M 7 85	10 6	280 6	266 4
Complement		77	76	76	9 9	0 8	0 0
Mean tith		15 00	6 61	M 8 61	20 5	281 4	266 4
Tab 6 ○ s eq Arg 281°			+ 17	+0 17	2 0	=(0 17	× 17)
Tab 7 ☾ s eq Arg 22			+ 17	+0 17	22 5		
Mid Eclipse on			6 95	M 8 95	Friday	4 48	A M

We must first calculate the value of D by Sec 163

D = 266 40 Rahu
281 40 ○ s anomaly
2 21 ○ s eqn × 13 = 17 + 13
0 17 ☾ s equation
—C 54 02 (23 — 50) Empi Corr
180 00 The eclipse being lunar

9 64

By Sec 165 we find the following values of v a l and p

Table 25 Arg ☾ s anom 22° 5	$v =$	730 0
26 Arg $v = 730$	$a =$	55 2
27 Arg D = 9° 6	$l =$	49 0
Magnitude $= (a - l) = (55 - 49)$	$=$	6 2
Magnitude in digits = 6 2 × 4	$=$	2 5
Table 28 Arg $(a - l)$ (a)	$p =$	130 0
semi duration in minutes	$=$	52 0

By Sec 167 $(m - p) = 4h\ 48\ m - 52\ m.$
$= 3h\ 56\ m$ Ecl begins
$(m + p) = 4h\ 48 + 52\ m$
$= 5h\ 40m$ Ecl ends

Example 2.—Calculate the Lunar Eclipse of September 1, B C 720 The magnitude was 6 digits It was observed at Babylon and is quoted by Ptolemy

We shall make use of the elements of the preceding example and add to them the increase for the interval of 180 tithis from Table 5

Prof Newcomb estimates the middle time for Ujjain as 9 P M

Calculation

Explanation	B C	T th	Vara	Date	☾ s anom	☉ s anom	—Rahu
Table	—720	15	6 61	M 8 61	20° 5	281° 4	266 4
5		100	0 43	98 43	206 1	97 0	5 2
5		80	1 75	78 75	308 8	77 6	4 2
Ashv n		195°	1 79	185 79	175 4	96 0	275 8
6 Arg 96° ☉ s eqn			— 18	— 18	—2 2	— 18	× 12
7 Arg 173° ☾ s eqn			+ 04	+ 04	173 2		
			1 65	185 65			
11 September 0				184 00			
September 1			1 65	1 65	= 9h	36 m	P M

Here D = 275° 8 Rahu
96 0 ☉ s anomaly
— 2 3 ☉ *s eqn* × 13 — 18 × 13
+ 0 0 ☾ *s eqn*
— 0 5 02 (23 — 50) *Emp corr*
180 0 The eclipse being lunar

Tab 27 Arg 189 0 $l = -45$ 0 ☾ s latitude south

Tab 25 Arg 173° 2	$v =$	857 (
Tab 26 Arg 857	$a =$	61 2
Magnitude $(a - l)$	—	16 2 = 6 5 digits.

Thus the preceding calculations confirm Ptolemy's statements as regards the magnitude of the lunar eclipse that happened 25 centuries ago, though we cannot vouch for the times which are themselves not precisely stated

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THE ECLIPSE OF THE SUN

170 Method.—Calculate as before the ending moment of the true New Moon, according to Secs 77 80 and then add the correction in time for the difference of longitude of the given place from the meridian of Ujjain

171 Calculate D as stated in Sec 163 and determine with it by means of the following limits the possibility or certainty of the eclipse at least somewhere on the earth's surface.

Solar ecliptic limits

A Solar eclipse is	Doubtful	Certain	Doubtful
If D lies between	341° — 347°	347° — 13°	13 — 19°
or ,,	161 — 167	167 — 193	193 — 199

172 To be able to say definitely whether a solar eclipse will be seen at a given place, the following 12 elements are necessary. Of them the first four elements are obtainable from tables and the rest must be calculated.

Elements

(a) Latitude and longitude of the place
(b) Latitude of the Moon, by D (Table 27).
(c) Diameter of the Moon, by ☾'s anomaly (Table 25)
(d) Diameter of the Sun, by ☉'s anomaly (Table annexed to Sec. 174)
(e) The approximate ghati of the apparent or local middle (M) of the eclipse, Arg. ghati of Amânta (New-moon), Table 29.
(f) The sun's tropical longitude by Sec. 173.
(g) Sidereal time T at apparent middle of the eclipse, by Sec. 174

(*h*) The Nati *i e*, the parallax in the latitude of the Moon Table 30 Arg T and latitude of the place

(*j*) The Moon s apparent latitude which is = (Moon s latitude ± Nati) = $(b + h)$

(*k*) Sum of semi-diameters of the Sun and the Moon = $\frac{1}{2}(c + d)$

(*l*) The Sun will be eclipsed at the given place if (*j*) is smaller than (*k*)

(*m*) The magnitude of the eclipse is equal to the remainder of $(k - j)$

173. The tropical longitude of the Sun (*f*) at the *moment* of the true New Moon can be calculated by the following formula

(*f*) = Tropical ☉° = ☉ s anomaly

+ 77° 3 ☉ s apogee

+ ☾ s equation

+ ☉ s eqn × 13

± Precession of equinox Tab 3

174 The sidereal time T at the time of the apparent middle of the eclipse, can be calculated by dividing by 6 the degrees of the sun s tropical longitude and adding the quotient to M the ghati of the apparent middle of the eclipse T is one of the arguments of Table 30 for finding out the Nati.

$$T = \frac{\text{Trop ☉ in degrees}}{6} + M$$

Table—Sun s diameter in minutes of arc.

Argument ☉ s anom.	0° 360	20° 340	40° 320	60° 300	80° 280	100° 260	120° 240	140 220	160° 200	180° 180
☉ s diameter	31 5	31 5	31 6	31 8	31 9	32 1	32 3	32 4	32 5	32 6

The Total Solar Eclipse observed at Nineveh

175. Example —We shall here calculate the great Eclipse of the Sun observed at Nineveh on 15th June B C. 763 in the

Hebrew month of Sivan The latitude of Nineveh is 36° 3 North and its longitude is 31° 5 West from Ujjain or — 0 09 day

Model of calculation by Secs 77—80

Table	B C	Tithi	Vāra	Date	☾ s anom	☉ s anom	Precession	Rahu
3	—801	17 98	1 98	M 6 98	110° 9	280° 6	—21°·7	130 9
4	36	8 33	3 31	0 31	75 4	0 0	0 6	386 7
4	2	22 13	2 52	0 52	184 2	0 0	0 0	38 7
	—763	18 44	0 81	M 7 81	10 5	280 6	21·1	154·3
Longi of Nineveh			— 09	— 09				
At Nineveh		18 44	0 72	M 7 72	10 5	280 6	—21°0	154 3
Compl		·56	55	55	7·1	0 5	0 0	0 0
S		19	1 27	M 8 27	17 6	281 1	—21·1	154 3
5 R		100	0 43	98 43	206 1	97 0	0 0	5 2
5 R		1	·98	98	12 9	1 0	0°0	0 0
T Ashādha 30		120	2 68	107 58	236 6	19 1	—21 1	159 5
6 Arg 19° ☉ s eqn			— 06	— 06	—0 7	(—0 06	×12)	=— 7
7 Arg 236° ☾ s eqn			— 33	— 33	235 9			
			2 29	107 29				
11 March 0 to June 0				92 00				
		June	Mon	15 29	29 ×	60 =	17 4	ghatis

From Table 29 Arg 17 4 gh we get M = 19 gh of Mid-eclipse

Let us first calculate D by Sec 163 the Sun s tropical longitud by Sec 173 and T by Sec 174

D = 159 5 Rahu

19 1 Sun s anomaly
—0 8 Sun s eqn × 13 = — 06 × 13
—0 3 Moon s eqn
—0 5 02 (23 — 50) Emp corr

177 0

By Secs. 173, 174.

Trop. ☉ = 19°·1 Sun's anomaly, as above.
77·3 Sun's apogee, constant.
— 0·8 Sun's equation × 13 = –·06 × 13.
— 0·3 Moon's equation.
— 21·1 Precession, Ayanâmsha. Tabs. 3, 4.
$(f) = \overline{74 \cdot 6}$

$$T = \frac{74 \cdot 6}{6} + 17 \cdot 4 = 29 \cdot 8 \text{ ghatis.}$$

We shall now proceed to calculate in succession all the elements from (a) to (m) described in Sec. 172.

Elements of the eclipse, at 19 ghatis at Nineveh.

(a) Latitude of Nineveh .. .. N.	36°·3
(b) ☾'s latitude, Tab 27 Arg. D = 177 .0 .. N.	15'·1
(c) ☾'s diameter Tab. 25 Arg. ☾'s anom. 236 0	32'·0
(d) ☉'s diameter. Sec. 174 Arg. ☉'s Anom. 19°	31'·5
(e) Ghati of Mid-eclipse Tab. 29, Arg. M = 17·4 gh.	19 ·0
(f) ☉'s trop. longitude as above calculated ..	74°·9
(g) Sidereal time T, as above calculated .. gh.	29 ·8
(h) Nati, Tab. 30, Arg. T and (a) .. .. —	13'·3
(j) ☾'s apparent latitude = (b + h)	1'·8
(k) Sum of semi-diameters of ☉ and ☾ = ½ (c + d)	31'·7

(l) Here j is smaller than k. Therefore the eclipse did take place at Nineveh.

(m) The greatest magnitude was k — j = 30' or 12 digits .. .. 30·0

It was a great solar eclipse. It passed centrally about 100 miles north of Nineveh. The diameter of the Moon being greater than that of the sun it was total and was, *therefore*, placed on record by the Assyrians of Nineveh.

The moments of first and last contact may be accurately *computed by means of the author's Ketaki or Jyotirganita.*

The great Solar Eclipse observed at Babylon

176. As a second Example, we will calculate below the great solar Eclipse observed at Babylon on July 31, 1063 B. C.

Elements of the Solar Eclipse seen at Babylon.

(Babylon meantime)

Monday, July 31, B C 1063

(a) Latitude of Babylon .. .. .. N		32°·5
(b) ☾'s latitude Tab 27 Arg D. .. .. N.		6'·4
(c) ☾'s diameter, Tab 25 Arg ☾'s anom 242 4		32' 0
(d) ☉'s dameter, Sec 174 Arg ☉'s anom, 67°		31'·8
(e) M time of middle of Eclipse .. .. gh		9·6
(f) ☉'s tropical longitude		116°·5
(g) T Sidereal Time at Mid-eclipse .. .. gh		29 0
(h) Nati, Tab 30, Arg T and Lat 32 5		—9'·5
(i) ☾'s apparent latitude = $(b + h)$ .. .		— 3' 1
(k) Sum of Semi-diameters of ☉ and ☾ = $\frac{1}{2}(c + d)$		— 31' 9
(l) $j < k$ Therefore eclipse was visible at Babylon		
(m) the magnitude was $(k - j)$ = or 28 8 × ·4 = 11 5 digits		28'·8

Note—In finding the magnitude the sign of (j) should be considered to be plus always

The eclipse was nearly as large as that observed at Nineveh on June 15,763 B C But in the present instance the central line of the Moon's shadow must have passed — 3' 1 × 70 = about 200 miles to the south of Babylon

The diameter of the sun being smaller than that of the moon the eclipse was total on the central line

CHAPTER XVI

Time

177 Time is simply an idea inseparably connected with the idea of motion or action So that both being concurrent, either of them can be considered as the measure of the other The year, month, day, hour, &c. measure, in the astronomical calculations, the

motion of the heavenly bodies, and conversely the motion of the heavenly bodies such as the Sun, the Moon and the planets is used in chronological calculations to measure time.

Smaller actions or motions are employed to measure smaller divisions of time. The pulsations were employed to measure time in India long before the time of Galileo. This is shewn by the fact that the celestial Equator is called Nâdi Mandala in all the ancient Siddhântas. Nâdi Mandala literally means the pulsation circle. In common parlance the smallest portion of time is expressed by the phrase 'the twinkling of an eye'. On the other hand distance is often expressed by the time taken to go over it. The vast stellar distances are expressed in astronomy by light years. Light travels at the inconceivable rate of 186,000 miles per second.

178 Before the invention of clocks and watches, the *Ghati kâpâtra*, the clepsydra and the sundial were employed to measure time, which generally commenced at sunrise, noon, or sunset. The time obtained from them was of course rather too rough to be used in accurate observations. The invention of chronometers served to give the greatest stimulus to the progress of astronomy. But finding that chronometers were incapable of following the capricious movements of the Sun, modern astronomers have called in the help of a fictitious point called the mean sun in the Siddhântas which is supposed to move always with uniform motion along the celestial equator. The astronomers know the exact interval by which the mean fictitious sun arrives at the meridian, either before or after the shining Sun. This interval is called the *equation of time*. It is therefore necessary to observe every day the meridian passage of the real Sun and to set the chronometers so as to show the position of the mean sun. An observatory is therefore indispensable if civil and public affairs are to be conducted in accordance with mean time. With this object in view western nations have built observatories at or near their capitals, from which correct mean time is every day wired to all the important places connected by railways and telegraphs. Lately mean time is communicated to steamers

at sea by means of wireless telegraphy, it being formerly obtained by the observation of lunar distances.

179. The time hitherto shown in the Tables and calculations is the *mean solar time of Ujjain (U. M. T.).* The meridian that passes through the old Observatory of Ujjain is used as the origin of longitude by all the Siddhântas. Ujjain is, therefore, the Greenwich of India. Its longitude is 75°46′·1 East of Greenwich and its latitude is 23° North.

Ujjain seems to owe this honour chiefly to its central position and to the fact that it was once the capital of one of the most powerful and enlightened king called Vikrama, whose era still prevails over the greater part of Northern India. He liberally patronized arts and sciences, and invited many learned men to his court.

180. The Indian Standard Time,—It is 5 hrs. 30 m. and 27 m. in advance of the Greenwich and Ujjain mean times respectively, and 2 minutes behind the Benares time. But mean times are not to be used in the performance of Hindu religious ceremonies. All the statements of time for this must be made in the Sâvana Time (*vide* Sec. 64) which is measured from the moment of the actual sunrise at the given place. For this purpose the Ghatikâpatra is used and its immersions in water are watched and noted with little vertical lines of kumkuma on the white background of a wall. The watchman (a Joshi) is afterwards paid his fee and thanked for his trouble and is invited to dine at the festival.

181. To convert meantime of Ujjain into Sâvana time of a given place. (*Vide* Sec. 64)

We need calculate only the two arguments, (*a*) and (*b*), to obtain the three corrections from one and the same Table 33. The latitude and the time difference of longitude from Ujjain can be obtained from maps or other sources, such as my Jyotirganita.

(*a*) The tropical longitude of the sun.

(*b*) The Sun's anomaly.

(*c*) The equinoxial shadow at a place can be obtained from Table 34, when its latitude is known.

To convert Ujjain meantime into sâvana time

THERE ARE TWO CASES:

First, when the given date is Luni-Solar

182 In the case of a luni-solar date the sun's anomaly becomes available in the course of its computation But the sun's tropical longitude must be calculated by the formula of Sec. 173

Method —(*a*) From Table 33, with the sun's tropical longitude take out the palas and multiply them by the digits of the equinoxial Shadow of the place The product will be the palas called *Chara*

(*b*) With double the number of the Sun's tropical longitude as argument, take out from the same table the palas and increase them by their seventh part and call them *Udayântara*

(*c*) With the sun's anomaly as third argument, take out from the same table the palas and call them *Bhujântara*

(*d*) *The Rekhântara* should be reckoned at 10 palas per degree of longitude measured from Ujjain, and is plus or minus according as the place lies to the east or west of the meridian of Ujjain

(*e*) Add the above four quantities to the mean time of Ujjain according to their signs, and the sum will be the *Sâvana Time* of the occurrence of the phenomenon at the given place

Sâvana Time = Ujjain mean time,
+ Chara
+ Udayântara,
+ Bhujântara,
+ Rekhântara

Example.—Calculate the Sâvana Time of the end of Ashâdha Shukla 12, Thursday, Shaka 406, at Eran Lat 24° N and Long 2 53' to the East of Ujjain The tithi ended at 51 gh. 11 pa (U M T)

This same tithi has been worked out in Sec 94, where the Sun's anomaly is 14° 5 Table 34 gives 5·34 digits for the equinoxial shadow for latitude 24° N

We have now to calculate only the Sun's tropical longitude by Sec. 173.

Thus—

Trop. ☉ = 14°·5 Sun's anomaly,
77·3 „ apogee,
—0·8 „ Eqn. × 13 = —·046 × 13
+0·4 ☾'s Equation.
—0·6 „ Precession for Shaka 406, Tabs. 3, 4.

90·8

With this preparation we can calculate the Sâvana time by Table 33, as follows :—

		gh.	pa.
Ujjain Mean Time		51	11·0
(Arg. 91°) for Chara ; 20·7 pal. × 5·34 = ..	+	1	50·5
(Arg. 182°) for Udayântara; — 0·65 × 8 ÷ 7 =	—	0	0·7
(Arg. 14°·5) for Bhujântara	+	0	4·8
Rekhântara + 2'·53 × 10 = ...	+	0	25·3
Sâvana time at Eran		53	29·9

— —

2ndly, When the given date is Solar.

183 In the case of solar dates which are used in Bengal, Orissa, Tamil and Malayâlam provinces, the arguments of Table 33 can be obtained by the following two formulæ.

Trop. ☉ = + Longitude of Sankrânti in Tables 13, 15 or 17.
+ Date of Solar month.
+ Precession, Tables 3, 4.
Sun's anomaly = Trop. ☉, as obtained above.
+ 282°·7 = (360 — 77°·3).
— Precession, by Tables 3, 4.

Note—The remaining procedure is exactly the same as given in Sec. 182.

184. Time of Sunrise, Noon and Sunset.—The three corrections Chara, Udayântara, and Bhujântara, calculated in Sec. 182, can also be employed in solving problems of sunrise, noon, and sunset in local time, as shown in the following formulæ.

Let C, U, and B, the initial letters, denote the three corrections in palas and, let (m) represent the factor 0·4 for changing them into minutes of time. (Sec. 64 Note.)

Formulæ.—

(*a*), Half day time $= 6\ h. + m\ C$
(*b*), Sunrise $= 6\ h - m\ (C + U + B)$
(*c*), Noon = Sunrise + Half day time
(*d*), Sunset = Noon + Half day time
(*e*), Equation of time $= -\ m\ (U + B)$

Note.—The time of sunrise obtained by the above formula must be lessened by 2 minutes, and the time of sunset must be increased by 2 minutes for the refraction of the Sun's rays at the horizon. For greater accuracy the 2 minutes must be multiplied by the secant of the latitude of the place

(1) When the given date is Luni-Solar

Example—Calculate the mean local time of the above phenomena at Eran, Lat. 24 N., on Ashâdha Shukla 12, of Shaka year 406

We make use of the corrections already computed in Section 182, *viz.*, Chara + 110 pa., Udayântara — 1 pa., and Bhujântara + 25 pa.

	Local mean time.
(*a*), Half daytime	$= 6h + {\cdot}4 \times 110$ $= 6h$ 44 minutes.
(*b*), Sunrise	$= 6h. - .4\ (110 - 1 + 5)$. $= 6h. -$ 46 minutes. $= 5h.$ 14 m (A. M.)
(*c*), Noon	$= 5h$ 14 m + $6h.$ 44m. $= 11h$ 58 m (A. M.)

(d) Sunset $= 11h\ 58\ m + 6h\ 44m$
$= 6h\ \ 42\ m$ (P M)

(e) Equation of time $= -4\ (-1 + 5)$
$= -1\ 6$ minutes

185. (2) When the date is Solar, we should calculate the arguments the sun s tropical longitude and anomaly according to Sec 183

We shall work out an example involving the highest latitude in India given in D B Pillai s Chronology page 27

Example 2.—Find the time of sunrise at Shrinagar Lat 34° North, on the 4th date of the Bengal Solar month Margashirsha in the Kaliyuga year 4325

Here by Table 34 the equinoctial shadow for latitude 34° is 8 1 digits

By Sec 183—

Trop ☉ = 210° 0 longitude of the sun Tab 13 on the first day of Margashirsha.

4 0	The date of Margasirsha		
11 0	Precession Tab 3 K Y		4301
0 4		4	24
225 4			4325

s anomaly = 225° 4 ☉ s tropical longitude,
282 7 = (360° − 77° 3)
−11 4 Precession Tabs. 3 4
136 7

Tab 33 —	Palas
Arg 225 4 for Chara (−14 1 × 8 1) −	− 114 2
90 8 for Udayantara (20 7 × 8 − 7) = .	+ 23 7
136 7 for Bhujantara	+ 14 2
Correction to be made to 6 hours A.M	− 76 3
Correction calculated by D B Pillai	− 75 0
Correction calculated by Prof Jacobi	− 74 0

By Sec. 184 eqn (b), 6h — ·4 (— 76 3) minutes
Sunrise = 6h 30·5m (A M)

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186 The Ishtakâla and Lagna —Owing to the apparent diurnal revolution of the heavens, all the degrees of the Ecliptic rise in succession upon the horizon of every place on the earth situated within 66 of Latitude In astrology the whole of the ecliptic is divided into 108 divisions called Navamâmshas or quarter nakshatras, each of which is presided over by a particular planet, the qualities of which are supposed to influence the actions at the place during the time which the Navamâmsha takes to rise fully above the horizon, and which usually lasts about 33 palas.

The properties of the Navamâmsha during which a child happens to be born are supposed to influence all its actions through life, although they are liable to modifications according to the effects of the aspects of the planets situated at different distances from the Navamâmsha It is the pivot on which the horoscope of an individual is made to turn and consequently its knowledge, correct to within a degree at least is essential to the astrologers

In the performance of any important business, the time of the rising of inauspicious Navamâmshas is to be avoided as far as possible

Hence arise the following two problems

187 Problem I —Given the Sun s sidereal longitude at sunrise, the auspicious degree of the Ecliptic (Lagna) and the latitude of the place, to find at what ghati of the Sâvana time (*Ishtakâla*) after sunrise, the auspicious degree of the Ecliptic will come in contact with the horizon

Rule —From Tables 3 and 4 take out the precessional degrees and deduct from them 22 50 algebraically and call the difference C, which is the correction for the precession

Add C to the Sun's longitude S, and to the lagna L, and call the sums (S + C) and (L + C)

From Table 36, with arguments, latitude and (S + C), take out sidereal time in ghatis entered in the first column of the table.

Again from table 36 with arguments latitude and (L + C) take out the sidereal time

Deduct the former sidereal time from the latter Then again deduct from the remainder as many Asus as there are ghatis in it six Asus being equal to one pala.

The result will be the *Ishtakala* or the desired Savana Time

Example—At how many ghatis and palas after sunrise was the 165th degree of the ecliptic in touch with the horizon (lagna) on the 6th day of the Bengal Solar month Jyestha in Kaliyuga year 4000 in Latitude 20 N at Puri in Orissa.

Tables 3 and 4 give 6 1 for the Ayanâmshas in Kali 4000 Therefore (6 1 — 22 5) = — 16 4 = C

Table 13 yields (30 + 5) = 35 for the longitude of the Sun on the 6th day of Jyestha

	Sun	Lagna
Longitudes of	35 0	165 0
Precessional correction C	— 16 4	— 16 4
Arg of Tab 36	18 6	148 6
	Sidereal time of rising of—	
	Sun	Lagna
	gh pa.	gh pa
Table 36 Arg Lat 20 and 18 6	5 30	0 0
Table 36 Arg Lat 20 and 148 6		28 25
Deduct	5 30	5 30
Duration in sidereal tim	0 0	22 55
Deduct 23 asus = 4 palas		— 4
Result — The Savana time when 165 0 was Lagna		22 51
By D B Pillai s Chronology page 30		22 52

188. Problem 2.—Given the Sun s longitude the Ishtakâla or Sâvana time and the latitude of the place to calculate the Lagna or the rising degree of the Ecliptic

Rule.—Calculate the Sun's sidereal time of rising as in problem 1 Add to this the Ishtakala and as many Asus as there are ghatis in it

With this sum as argument of Table 36 and under the given latitude in it, calculate the Lagna and add C to it with its sign reversed The result will be the *Lagna* sought

Example 2—What degree of the Ecliptic was Lagna or rising at the same place and date at the end of the 20th ghati ?

The sidereal time at sunrise is in the above example 5 gh. 30 pa Thus increased by the Ishtakala, 20 gh and as many asus (20 = 3 palas) amounts to 25 gh 33 pa as the sidereal time which is the Vertical Argument of Table 36 Opposite to this and under 20° of latitude we get for Lagna 132° 5 Adding to this C with its sign reversed viz, 16° 4 we get for the Lagna or the rising degree of the Ecliptic 148° 9

Type of calculation	gh pa
Sidereal time at sunrise as before	5 30
Add the Ishtakala 20 gh	20 0
Add 20 asus = 3 palas	0 3
Sidereal time at 20 gh Savana time	25 33
	Lagna
Tab 36 Arg 25 gh 33 pa and 20° lat	132° 5
Add C —16 4 with its sign changed	+16 4
Result —The Lagna at 20 gh .	148 9
Result reached by D B Pilla, and Prof Jacobi .	149 0

CHAPTER XVII

MISCELLANEOUS NOTES

In this chapter we mean to add for advanced readers a few notes on questions relating to theory explanation, comment and antiquary

NOTE 1

189 The beginning of Kaliyuga.—According to the Sûrya Siddhânta, the Kaliyuga which is a cycle of 432000 years, commenced at mid night of Lankâ on Thursday, the 17 75th of February 3102 B C This means that the first point of Ashvini on the Ecliptic, the mean sun, and the mean moon, reached simultaneously the lower meridian of *Lankâ* an imaginary spot on the Equator on the meridian of Ujjain The Siddhânta further states that at this moment the longitudes of the apogees of the Sun and the Moon were 77° 26 and 90° respectively

190 But as the functions of civil life depend upon the true positions of the sun the *almanac-makers* seem to have rejected the mean zero moment of the zero year of the Kaliyuga and to have adopted in its place, for convenience's sake, that moment for zero, at which the centre of the *true sun* arrived at the first point of Ashvini usually called Ashviniyadi

This *True Epoch* of chronology, when calculated with the elements of the Sûrya Siddhânta, precedes the midnight of Lankâ by 2 1707 days It, therefore, occurred on the 17 75 — 2 1707 = 15 5793th day of February 3102 B C At this moment the mean longitude of the Sun was 357°·862 and the equation of its centre was + 2° 138

191 The Ahargana or the days elapsed from the *Mean Epoch* of Kaliyuga, *i e*, from 17 75th of February, 3102 B C., is often required in the planetary computations of the Sûrya Siddhânta It is easily obtained by multiplying the days of the Solar year 365 258756484 by the number of years elapsed upto the Meshâdi of any given year, and deducting from the product the constant number, 2 1707 days This constant number is called *Shodhya*, meaning a subtrahend. It has no application in chronology

NOTE 2

192. Transformation of the chronological elements into Astronomical ones.—This is sometimes necessary for the purpose

of comparison with the latter, when available from an independent source. The transformation can be easily effected by means of the following formulæ.

The apogee of the Sun is supposed to be motionless. Its longitude is, therefore, always 77 ·26 from the first point of Ashvini.

Let S, M, A and N denote the mean longitudes of the Sun, the Moon, the Moon's Apogee and Node (Rāhu).

Then—

S = 77 26 + Sun's anomaly
M = S + (tithi × 12)
A = M — Moon's anomaly
N = 77 26 — (Râhu) .. given in Table 3

Example.—We shall calculate the values of S, M, A and N for the moment of the true epoch of Kaliyuga, the year of Table 3.

Putting the chronological elements in their proper places in the preceding formulæ and solving them, we have—

S	= 77 26 + 280 60 = 357 86	. ☉'s longitude.
M	= 357 86 + (27 795 × 12) = 331 40	☾'s longitude.
A	= 331 40 — 241 57 = 89 83	.. ☾'s apogee.
N	= 77 26 — 235 18 = 202 08	☾'s node

NOTE 3

193 Method of testing the accuracy of the consecutive and equidistant *mean elements* given in Tables 3, 4, 5, 14, 16, 18, 20 and 23, and of finding out a new one, that is not given in them. *The elements affected by Bija* or by abrupt changes due to the introduction of the Gregorian Style are exceptions. The accuracy of the figures of the remaining tables which are mostly sine-functions, may be examined by taking their first and second differences which ought to rise or fall uniformly without a hitch if they are correct.

If A, B C be any consecutive and equidistant mean quantities then they must satisfy the following equations —

$$2\,B = A + C$$
$$A = 2\,B - C$$
$$C = 2\,B - A$$

Example 1 — Suppose we want to test the accuracy of Samvat 36 112 for Kali year 3001 given in Table 20 Part A we should proceed thus —

Kali		Samvat	2 B	A + C
3001	A	36 112	39 622	36 112
3301	B	39 622	39 622	43 132
3601	C	43 132	19 244	= 19 244

Here the first equation is satisfied Therefore the quantity 36 112 is correct

Example 2 — Suppose we want to know the Samvat for Kali year 2601 which is not given in Table 20 We can obtain it in the following way —

Kali Yuga			Samvat
2601	A		unknown
3201	B	=	58 452
3801	C	=	5 472

$$A = 2\,B - C = 56\ 904 - 5\ 472 = 51\ 432 \text{ Ans}$$

Example 3 —Suppose we intend to examine the accuracy of the figures in the 2nd column of Table 6 which vary as the sine of the suns anomaly We should do it thus —

Argument—			6		12		18		24		30		36°
Figures—	0		19				56		74		90		106
1st diff		19		19		18		18		16		16	
2nd diff			0		1		(		2		0		

Here the first differences decrease pretty uniformly. But as we have omitted the fourth decimals, the hitch in the 2nd differences is unavoidable, and being too small, may be overlooked The figures are therefore accurate enough The last decimals are generally in error not exceeding half a unit for the same reason.

Note 4

tabulated values of moon's anomaly in Table 7 For this purpose we must first multiply N by the fraction D/m in order to get the increase in arc in the Moon's equation of centre, and then divide the product by l to get its value in time Consequently,

$$\therefore \quad E' = \frac{N \ D}{m \ l}$$

These two formulæ are similar and can therefore, be combined to obtain the two values by a single effort Thus—

$$E + E' = \frac{(S + N) D}{m \ l} \qquad Q \ E \ D$$

195 The *variation* in the daily motion of the sun being too small *viz*, about 2 it can be ignored and the sun s mean daily motion 59 can be used as a constant in the divisor in calculating the equations in time of the sun and the moon The addition of the moon s equation to the Sun s anomaly, though required by the above theory is practically of no value For the moon's equation in time (See Table 7) amounts at its maximum to less than half a day, during which time the sun s equation of centre in arc can vary, at the most only by one minute of arc or by five palas which are practically negligible

196 We shall *illustrate* the foregoing theory by a numerical example worked out according to the method of the Indian Jyotishis For this purpose we select the example worked out in Sec. 82 and take from it the anomalies of the moon and the sun which are 341° 1 and 236° 2 respectively With these arguments, we obtain from Tables 32 and 31 their equations of centre, + 98 1 and 108' 6, respectively Also Table 25 gives 729 for the moon s true daily motion for that day, and we may assume 59 for the sun s motion

The usual Indian method of calculating the correction to the ending moment of a tithi, due to the equations of centre which

they call *Parakhya Samskâra* can be easily understood from the following working —

☾ s eqn	☉ s eqn		☾ s		☉ s		Total
$\frac{(-98\ 1+108\ 6)}{(729-59)}$		$=-$	$147\,d$	$+$	$162\,d$	$=+$	$015\,d$
While we get from Tables 7 6		$-$	$133\,d$	$+$	$149\,d$	$=+$	$016\,d$

The Sun s equation $+149\,d$ obtained from Table 6 by employing the moon s mean daily motion 791 is as it ought to be less by about 013 d than 162 d obtained by employing the true motion 729 To make up this deficiency theory tell us that we should add 108 6 − 1 80 to the moon s anomaly 341 0 (See Type of calculation under Sec 82) and that with the argument 342 8 we should find from table 7 the moon s equation — 133 d which is equal to — 147 d + 013 d = — 134 day The totals in both the cases being identical clearly prove the compensation

NOTE 5

197 **The Theory** of the calculation of the interval passing between the mean sunrise at Ujjain and the actual sunrise at a given place (*vide* Sec 182) is based on the following four assumptions viz that (1) the Sun moves with its mean motion (2) in the Celestial Equator and that (3) all the towns on the earth have neither longitudes (4) nor latitudes but are crowded together as in an ant hill in the central point of Lanka on the Equator As none of these assumptions is real corrections must be made for each individual assumption to the extent of its deviation

The first assumption is corrected by the *Bhujantara* i e the equation of the Sun s centre the second is corrected by the *Udayântara* i e the Right Ascensional difference due to the obliquity of the Ecliptic. The third is corrected by the *Rekhâ tara* i e longitude and the fourth by *Chara* which is equal to the excess or defect of the semi-diurnal duration as compared with 6 hours

Note 6

198. Tables.—Table 2 (parts I and II) of the Adhika and Kshaya months, originally computed by Prof. Kero Laxman Chhatre, is copied from a magazine published in Bombay by the *Djnânaprasâraka-Mândali* in 1851. It is corrected in a few cases by Messrs. Sewell and Dixit, and D. B Pillai.

Tables 19, 20 and 24 have been adopted from D B. Pillai's Chronology. Table 19 is too simple. D. B. Pillai has not taken the trouble to explain the construction of Tables 20 and 24, a defect which has been made good here with a full explanation. (*Vide* Secs. 121 and 150.) At the very outset in Chapter XI we have in Sec. 120 furnished a formula to which Table 20 may be considered as auxiliary.

The rest of the tables are either specially prepared for this book, or are derived from the author's own treatises.

Tables of increase of elements for odd years and tithis of the Ârya and Brahma Siddhântas are not given, the occasion for their use being rare. Those given for the Sûrya Sidhânta can be used in their place without appreciable error, as can be seen from the examples worked in Sec. 106, and also from Table 37 of the Constants at the end.

The longitude of (Râhu), as given in Col 7 of Table 3, is the supplement of the distance of the Moon's Node from the Sun's apogee. It is derived from the author's Marathi Grahaganita.

Note 7

199 Bija or Empirical correction—It is an Indian Astronomical maxim that the mean positions, after long intervals, require empirical correction. '*Yugânâm parivartena Kâlabhedotra, Kevalam*' says the Sûrya Siddhânta. By 'Kâlabheda' is meant the empirical correction that is not capable of being explained by theory but by a change in the mean motions or by considering it as an arbitrary constant.

Makaranda Lalla and Rajamrigânka have respectively suggested empirical corrections to the Sûrya, Ârya and Brahma Siddhantas

(a) The revolutions of Jupiter in a Mahâ Yuga, when corrected for the Bija proposed by Makaranda come to 364212, while those according to Surya Siddhânta are 364220

(b) The Bija correction to be made to the Moon s anomaly in A D 1600 is + 1° 56 according to Ganesh Daivajna This same correction amounts to + 1° 70 when calculated by Burg s Lunar Tables

(c) The Bija corrections which must be made to the mean elements of the Surya Siddhanta so that they may agree with the mean elements of the Nautical Almanac are in the case of tithis—

+ 0 014 day to vara

+ 0 014 day to English date

+ o 330 degrees to the moon s anomaly

These will serve as empirical corrections for a period of one or two centuries in future

NOTE 8

200 The First point of Ashvini —Unfortunately there is no bright and unmistakable star near the Ecliptic, either in or near the first point of the first sidereal division of the Hindus called Ashvini worthy of being referred to as the origin of all the sidereal longitudes Luckily however there lies in the opposite direction and near the Ecliptic the single and brilliant star Chitra (Spica) the cynosure of all the ancient astronomers The Indian astronomers deserve therefore high praise for their decision to fix the origin of longitudes at a point diametrically opposite to Chitra which is of Vedic renown As there are two equinoxial points in the Ecliptic diametrically opposite to each other the Ayanamshas determined with reference to either of them must be equally correct

I shall now show that the general consensus of opinions is in favour of the choice of Chitra by quotations both from the works of ancient and modern astronomers and scholars in India

(a) The most ancient and famous Indian astronomer (वराहमिहिर) Varâhamihira (A D 505) has given in his Pancha Siddhantika (पंचसिद्धान्तिका) the following verse while stating the latitudes and longitudes of only such stars as could be seen occulted by the moon

> पित्र्यस्य स्वक्षेत्रे षष्ठे चान्द्रो मघायोग ॥ (अ १४ श्लो ३६)
>
> चित्रार्धप्रमभागे दक्षिणत सार्धहस्ते त्रिभिर्हस्ते ॥ (अ १४ श्लो ३७)

This important verse was recently brought to my notice by my friend Mr N V Kolhatkar B A Head Master Training School Alibag

The meaning of the verse is plain enough Herein Varahamihira states the positions or the longitudes of the moon when she occults the stars Regulus (मघा) and Spica (चित्रा) or in other word he states the longitudes of the two stars The moon he says occults Regulus when she arrives at the sixth degree of the Pitrya nakshatra-division and she occults Spica when she arrives at the middle point of the Chitra nakshatra division and has three cubits of south latitude a cubit being equal to 54 4

Now the Pitrya division begins at the 120° of longitude consequently the longitude of Regulus must be 126° Chitra being the 14th division the longitude of Spica which corresponds to its middle point must be exactly 180 Both these longitudes agree in fixing the same first point of Ashvini which is diametrically opposite to the star Spica and is about 40 to the east of the star called mu Piscium The 6th cycle ends in A D 291 (Sec. 152) when the tropical longitude of Spica was 180 , and the tropical system came to an end giving place to the sidereal

(b) In respect of the 14th chapter wherein Varâhamihira has given the above verse Dr Thibaut asks in his introduction p 41 " Why Varâhamihira should have confined himself to stating the longitudes and latitudes of seven junction-stars only remains

unaccounted for Possibly the manuscripts are defective just at that place

The question is not so difficult as Dr Thibaut thinks it to be Varahamihira wanted to give a list of such bright stars, the occultation of which by the moon could be seen by the naked eye For this reason he has omitted all the stars whose latitudes exceeded five degrees and also smaller stars of the third magnitude and below, which disappear on the approach of the moon The bright star Jyestha seems to be omitted as lying on the border of the zone of occultation The stars Pushya and Ashlesha given in the list must be as their latitudes show different from those given in the later lists of Yoga taras It being a list of occultation stars Varahamihira is justified in selecting the 7 stars only I have done the same in my Jyotirganita page 325

In another place (Introduction, p 40) Dr Thibaut says a few remarks may be added about what Varahamihira states in XIV (33 38) about the longitudes and latitudes of certain stars What authority he follows therein we are unable to say

The answer to this question is given by Varâhamihira himself fourteen centuries ago in the following verse in his बृहत्संहिता edited by Dr Kern

युद्धं यथा यदा वा भविष्यदादिश्यते त्रिकालज्ञैः
तद्विज्ञानं करणे मया कृतं सूर्यसिद्धांतात् ॥ (अ १७ श्लो १)

भटोत्पल —मया करणे पचसिद्धांतिकाख्या सूर्यसिद्धांतादानीय कृतमिति ।

Here by Karana is meant पचसिद्धांतिका and the Sûrya Siddhanta is the original or the old one and not the new or the later one which is now available The above queries of Dr Thibaut were brought to notice by my son D V Ketkar B A and the explanations given were also suggested by him

It should be noted that the words युद्ध and समागम mean the occultation or a near appulse or approach of two heavenly bodies The Sanskrit word योगतारा should I think be rendered by Conjunction star and not by Junction star, as Dr Thibaut has rendered it in his Introduction to पचसिद्धांतिका

(c) The old siddhântas such as the Sûrya S°, the Sôma S°, the Brahma S° and the Vriddha-Vasistha S°, have all assigned 180° for the longitude of the star Chitrâ

The modern astronomers, Mishra Nandrâmji (Shaka 1665) Jyotishroy Kevalarâmji (Shaka 1651) of Jaipur, and Chandra Shekhar Sinha of Cuttock, who were also skilful observers have adopted, in their works, the Ayanâmshâs, determined from the observations of the distance of the star Chitra from the Autumnal Equinox

(d) Great scholars like Mahâmahopâdhyâya Sudhâkara Dwivedi of Benares, Shriyuta Lâlachandra Sharmâ of Jaipur and the late A R Râjarâja Varmâ, M A, Principal, Sanskrit College, Trivendrum, have in their pamphlets strongly supported the course of fixing the first point of Ashvini situated at 180° from the bright star Chitrâ

(e) Sir William Jones in Vol IV of his works, says "The *Lunar year of 360 days (tithis) is apparently more ancient than* the solar, and began, as we may infer from a verse in the Matsya Purâna with the month of Âshvina, so called because the moon was at the full, when that name was imposed on the first lunar station of the Hindoo Ecliptic the origin of which, being diametrically opposite to the bright star Chitrâ (*i e*, Spica), may be ascertained on our sphere with exactness"

(f) Mr Davis was a civil servant of the East India Company in A. D 1790 at Bhâgalpore In one of his papers published in the second and third volumes of the "Asiatic Researches," Bengal, he says about the Hindoo Ecliptic, "Its origin is considered as distant 180° in longitude from Spica a star which seems to have been of great use in regulating their astronomy and to which the Hindoo tables of the best authority agree in assigning six signs of longitude counting from the beginning of Asvini their first nakshatra"

(g) M P. Khareghat, Esq, I C S (now retired), says in his article on the Interpretation of certain passages in the Panch-Siddhântikâ of Varâhamihira, published in Vol. XIX, of the Journal

of the Bombay Branch of the Royal Asiatic Society, A D 1895, on page 134:—" The Epoch of the Pitâmaha Siddhânta is the second year of the Shaka Era Mâgha Sukla 1, when the Sun and Moon were in conjunction at sunrise in the beginning of Dhanisthâ The data are correct, for on Tuesday, 11th January 80, A D, the sun and moon were in conjunction in Dhanisthâ in the morning But the conjunction took place not in the beginning of the nakshatra, as now understood, but very near the true longitude of the star Dhanisthâ (Alpha Delphini) The sun was then in the 21st degree from the winter solstice of that year, and in the 27th degree of Capricornus of the moveable Hindu Zodiac, the true longitude of the star is also in the 27th degree of Capricornus This is extremely important as fixing the true position of the Hindu Zodiac before the introduction of the Babylonian system of signs, Asvini according to this system must have commenced three degrees more to the east than it does now"

(h) From all the above opinions it is clearly manifest that the first point of Asvini was fixed diametrically opposite to the star Chitra, and that its epoch was Shaka year 213 or A D 291, (p 108) Should the reader desire the authority of an Indian observer it is afforded by the above Pitâmaha Siddhântâ, the oldest of all According to this Siddhânta the longitude of the Star Dhanistha was 291 degrees in Shaka year 2 Of course the longitude of Chitrâ must in that year be $(291 - 114) = 177$ degrees From these facts we deduce by means of the precessional motion the Shaka year to be $(2 + 210) = 212$ when the longitude of Chitrâ was $(177 + 3) = 180$ degrees

REFORMATION OF THE HINDU CALENDAR

(i) From what has been stated in Sec 152 the reader will be convinced that the star spica was the main Bench Mark of the Sidotropical system of the Aryan Chronology from B C 1193 to A D 291 In the latter year its longitude was exactly 180°, and on this account the year A D 291 was considered as a proper epoch for the commencement of a purely sidereal system of Chronology But the movement seems to have been opposed by the orthodox,* till at last Âryanâtha succeeded in overcoming

* The Libration of the Equinoxes was a subsequent invention calculated to pacify the just fears of the orthodox that the Vernal Equinox would go far away from the month of Chaitra.

their opposition [*vide* Sec 152 (c)] by archly adopting for the counter point of Chitrâ a slowly moving point about 10 degrees west of it, and an erroneous sidereal year about 7 palas in excess of that of the ancient Âryans We must therefore correct these two radical errors if we mean to carry out a thorough reform

As regards the starting point, the reform will not be a startling one Because the Epoch of the Meshadi of the Surya S° for Shaka year 1844 as calculated by sec 77, falls on April 13 312 and the true longitude of the Sun for the same Epoch, as calculated from Ketaki (2 cyc 2200 days) is found to be 359° 88 So the distance between the Chitra counter point and the moving starting point which was 10 degrees in the beginning of Kaliyuga is at present reduced to — 7 minutes only So also the substitution of the real sidereal year for the erroneous one will secure the fixity of the starting point for all time to come

We have announced these fundamental reforms in the introductory part of our Ketaki in the following verses —

भांशे चित्राभभोगो भगणदलमिति १८०° स्पष्टमुक्तं मयेन
तस्मात् तत्तारकाया अयनविषुवयोर्वृत्तयोर्वै द्वितीयात् ।
सम्पातात् क्रान्तिवृत्ते प्रगमितविवरेणायनांशैश्च भाव्यम्
तत्स्वाभ्रार्केन्दु (१८००) शाके यमनयनकला २२° नवांशैः ९' किलासीत् ॥
सौरोक्त शरद प्रमाणमयना सार्धं पलैरष्टभि
र्यस्माद्धिकतर हि वेधनिपुणै प्रत्यक्षतो लक्ष्यते ।
चसु प्राक् किल वर्तमानघन्ना दृष्ट्वा मुहु सूर्य
शुद्धिं तद्विहापि वेधनतार्द्दर्थं मया स्वीकृतम् ॥४॥

SPREAD OF THE REFORMED KETAKI CALENDAR

We have been publishing our Ketaki Panchanga containing these and other reforms for the last 25 years and similar Panchângas calculated on the basis of our Ketaki, Vaijayanti and Graha ganita, are annually being published in different parts and languages of India as at Puttur in South Canara at Belgaum in Mahârâstra at Elichpur in the Berars, and at Mathura in Upper India.

Learned men like Pt Madan-Mohan Mâlaviya, M A, of Allahabad, and Prof. Jogesh Chandra Ray, M A, of Bankura (Bengal), are at present earnestly considering the pressing need of the calendar reform, and the necessity of erecting and conducting suitable observatories for testing the accuracy of Calendars by direct observations It is to be hoped that sound counsels will ultimately prevail with them and that they will succeed in the near future in their commendable desire

NOTE 9

201 The date of the Mahâbhârata and Bhagavadgitâ, B C 470—The late Mr K T Telang has, in his learned introduction to the translation of the Bhagvadgîtâ, (part of the Series of the Sacred Books of the East, Vol VIII), attempted and almost succeeded in solving this important problem Beginning from Shankarâchârya (8th century A D) he has by means of references and allusions skilfully traced his way up, step by step, through the books of Bana Kâlidâs Panchatantra, Âpastamba, Patanjali, Baudhâyana, and Pânini (4th century B C) and laid down his conclusion in the following words on page 34 "We may, I think lay it down as more than probable, that the latest date, in which the Gitâ can have been composed must be earlier than the third century B C, though it is at present impossible to say how much earlier"

(a) Mr B G Tilak has made use of this same method in his Marathi Gitâ Rahasya (p 557) He has ultimately expressed his opinion that the date of the Mahâbhârata cannot be carried more than 500 years before the Shaka Era Thus both Messrs Telang and Tilak assign the 4th century B C for the date of the Gita. However, these methods are indirect and yield negative and often vague results I have, however, caught hold of a chronological allusion made in the Bhagavadgitâ, and making use of a contemporary historical event described in the Mahâbhârata, and also of the tables of the Ancient Aryan Chronology, have, I believe, completely and definitely solved the problem

(b) In identifying himself with the first, foremost, and the best of each kind of things the Divine Shrikrishna says in the Bhagavadgitâ, X. 35.

necessary to introduce by a royal mandate the new custom of counting from Shravana This is one out of many instances of the manner how pure truths are often disguised in the puranic myths of India in order to perpetuate them in peoples memory The legends about Sagara Bhagiratha and Agastya disclose when properly considered important facts in regard to the vast changes in the Earth s surface The reader may refer for information to my paper read before the First Oriental Conference held at Poona in A D 1919 and recently published in Vol II of its transactions in A D 1923

NOTE 10

202 Largeteau s Method —The principle of expressing the arguments of inequalit es in days of their periods is called Largeteau s Method It appeared first in 1846 as an addition to the French Connaissance des Temps Its great merit lies in that it saves completely the time and trouble of computing the arguments This is very des rable when the number of arguments is unusually large The arguments when once computed for any date are by this method at once changed into those for any other date by simply add ng to them all the same number of the inter vening days For this reason the method has been adopted by Hansen and Delaunay in their lunar tables which contain respectively 52 and 76 inequal ties of the Moon s longitude alone Prof E W Brown has also recently done the same in his lunar tables

(a) But the case of Indian Chronology in which only two inequalities are involved differs much from that of the Lunar theory in wh ch there arises no necessity of retransforming the periods of arguments into spaces or arcs In Indian Chronology the way to Nakshatra and Yoga lies through the Sun s anomaly (See Sec 92) which when expressed in days as is done by D B Pillai renders the passage very difficult and the explana t ons unintell gible For instance the reader might refer to D B Pillai s Chronology Chapter XXVIII

(*b*) The method of successive approximations employed by Messrs Sewell and Dixit in their Indian Calendar is also objectionable on account of its being very tiresome to the computer Mr Pillai has however the credit of securing both ease and accuracy of computation by voluntarily and generously undergoing himself once for all all the worry of successive approximations by vastly extending the tables See his table IX extending over twelve pages

NOTE 11

The Gavamayana Sacrifices

203 The Earliest efforts of the Aryans for Chronology —The correct knowledge of time being considered of vital importance in spiritual and religious matters the duty of keeping correct account of time was entrusted to the *Priests* who were called the Grama purohitas For this purpose they instituted daily yearly quadrennial and Epoch making sacrifices in which not only the gentry but even kings took part It appears from the Purana Nirikshana of the late Mr T G Kale and from the Gavamayana of Pandit R Shamashastri of Mysore that about the time of the Shatapatha Brahmana (B C 3100) an era was started by the Aryans in which the priests kept up the count of time by celebrating the Gavamayanas or the leap-year sacrifices every fourth year There is preserved says R. *Shâmshastri* a record called Brihadukta of 460 such sacrifices The era thus lasted 1840 years and ended in about (3100 — 1840) = 1260 B C giving place to Vedanga Jyotisha and to the grand cycle era of the Aryans (*Vide* Sec 152) The years were called in due order Kali Dvapara Treta and Krita in succession as the following verse implies —

कलि शयानो भवति सञ्जिहानस्तु द्वापर
उत्तिष्ठन् त्रेता भवति चरन् सम्पद्यते कृतम् ॥

Note—The order of years in this is direct and not reversed like that of the later unwieldy Yugas

This verse mentions that Kali or the first year begins at sunset the Dwapara at midnight the Treta at sunrise and the Krita at Noon Instead of adding one day at the end of the fourth year, the original practice seems to commence each year 6 hours later than the preceding

The similarity in sound of words for the intercalary days used in India Persia and Egypt *viz* Gavamayana Gambar and Epagomen is very striking and suggestive

The Indian Chronology can be briefly divided into 3 great periods

B C 3100 to 1200 B C The Gavamayana Period
B C 1200 to 300 A D The Grand Cyclic Period
A D 300 to 1900 A D The Siddhanta Period

Or still better into two divisions, *viz*, the pre Chitra and the post Chitra periods which are separated by the year A D 291

NOTE 12

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204 Assyria, the land of Astrology and Astronomy — The reference to Asuras in the Shatapatha Brahmana (Khanda VI 1 4) as being more advanced in their knowledge of the seasons is a proof of their civilization being at least as ancient as that of the Aryans whom they soon left far behind in arts and sciences The Assyrians assisted by the Chaldeans founded mighty empires built great cities and established astronomical observatories at their capitals so that at present Assyriology forms an important branch of Antiquarian research

The Assyrian Empire was at the height of its glory in the reign of Shalmanesar, B C 851 Ptolemy of Alexandria has based his calculations in his Almagest on the Assyrian Era of Nabonassar, which commenced on the 26th of February B C 747 (*Vide* Sec. 152, Ex. 2) Berosus the historian told Alexander the Great that 10 kings ruled before the Deluge for 432000 years, *i e*, for 120 Saroi, each of 3600 years

Although the statement is apparently impossible (*Vide* Sec 210 (c)) yet the number 432000 is very important as it is exactly equal to the years of Kaliyuga There were royal observatories at *Ur* and *Chaldæa* and the Royal astronomers had to submit their reports about their observations twice a month They used the gnomon and astrolabe in their observations They marked the Signs of the Zodiac about B C 2200 The cycle of the eclipses was known to them, and the week of 7 days was also in use They had cycles of 600, 60, and 3600 years called respectively Neras, Sossus and Sarus (Encyclopædia Britannica ninth edition)

205 Under such a state of civilized polity and imperial patronage and encouragement to Astronomy it would be unjust to deny to the Assyrian Astronomers the honour of being the first to compile an original work on mathematical astronomy, based on eccentric theory The countries included in the Assyrian Empire, have even in later years, produced the best observing astronomers Among them may be mentioned, Al Mamun Thebit, Albateni, Alhassan and Ulugbeg (Fig 4)

NOTE 13

206 Gradual spread of the Assyrian Astronomy—It is quite natural for the Western scholars to be partial to their brethren the Greeks. They allege, without any strong and indisputable evidence, that the Hindus must have borrowed their astronomy from the Greeks On the other hand they admit that the Hindu astronomy is much superior to the Greek in several details, and contains proofs of original and independent development Had I got a copy of Ptolemy's Syntaxis or of its translation called the Almagest I could have discussed and decided this question much better than I can at present with the second hand and limited information picked up from encyclopædias and other books of reference

If at all the Hindus have borrowed from the Greeks any science if we can use the word it is the Astrology which is now discarded as groundless by astronomers and scientists and which they (the

Greeks) themselves had borrowed from the Chaldeans The Hindus frankly acknowledge this fact Varahmihira quotes in his Brihatsamhitâ

म्लेच्छा हि यवनास्तेषु सम्यक्शास्त्रमिदं स्थितम् ।

ऋषिवत्तेऽपि पूज्यते किं पुनर्दैवविद्द्विजः ॥ (गार्गीसंहिता ।)

After calmly considering all the facts and possibilities connected with this question it appears most likely to me, that both the Greeks and the Hindus must have borrowed their knowledge of Astronomy directly from the Assyrian astronomers of Babylon at different periods of its development By this supposition we can account for and reconcile the agreements and differences of the two schools of astronomy so remarkable for the likeness of their terminology* and progress

Small Assyrian astronomical tracts on which the Romaka, Pulisha and Saura Siddhantas were based seem to have reached India as noticed before about the second or the third century A D Similar compendiums might have been carried from Babylon in the time of Hipparchus or a century or two later in the time of Ptolemy 150 A D as the map (Fig 4) shows, to Egypt, Greece and the civilized countries on the borders of the Assyrian Empire

It is a curious fact that almost all the astronomical works in India have used the Shaka Era as the basis of their computation This suggests that the Assyrian astronomical tracts might have first entered India by the route of the Persian Gulf through the Deccan with the Shaka invaders who established themselves as kings at Paithan on the Godavari

The Mahomedan conquerors of Egypt carried with them Ptolemy s Almagest to Spain in A D 1100 whence it was gradually adapted to the European mode of calculations

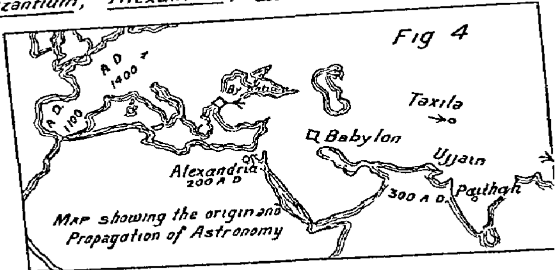
NOTE 14

207 Babylon was the home of Mayasura—It is quite natural that one should desire to know the place where Mayasura,

* Thus the words *hora kendra* and *lipta* which are made the topic of a hot discussion lose their importance They are neither Sanskrit nor Greek, but Chaldean

Byzantium, Alexandria; Ujjain, Paithan

Fig 4



Map showing the origin and Propagation of Astronomy

the Assyrian author of so eminent a work as Surya Siddhanta lived In the sequel we hope to answer this question most conclusively by direct evidence from the Shakalyokta Brahma Siddhanta and by the indirect evidence of the Súrya Siddhanta itself

The first eight verses of the Surya Siddhanta describe in the Puranic style how Mayasura intent upon acquiring the sacred knowledge of Astronomy practised the most difficult penance to please the Sun and how the Sun himself being pleased gave him *the knowledge about the movement of the planets*

The following are the verses—The dialogue is mentioned as having taken place when the Krita-Yuga was nearing its end

अल्पावशिष्टे तु कृते मयनामा महासुर ।
आराधयन् विवस्वन्त तपस्तेपे सुदुश्चरम् ॥
तोषितस्तपसा तेन प्रीतस्तस्मै वरार्थिने
ग्रहाणा चरित प्रादान्मयाय सविता स्वयम् ॥

208 The following verse mentioning the place where the dialogue between the sun and Maya took place occurs in the Shakalyokta Brahma Siddhanta Adhyaya 1 verse 168

भूमिकक्षाद्वादशांशे लङ्कायाः प्राक् च शाल्मले ।
मयाय प्रथमे प्रश्ने सूर्यवाक्यमिदं भवेत् ॥

The meaning of this verse is that the sun replied to the first question of Maya at *Shalmala* probably connected with Shalmanesar from which the longitude of Lanka is equal to one twelfth of the Earth s circumference (*i e* 30 degrees) eastwards The city of Shalmala can therefore, be no other than Babylon from which the Longitude of Lanka (Ujjain) is according to modern determination 31° 15 East The Arabs still call *Babylon* Sham

The longitude is here stated according to the Tulansha system which was peculiar to the Chaldeans and Assyrians and it is therefore an additional evidence of the Surya Siddhanta being Assyrian

In this system the directions of longitudes and latitudes are stated in a sense opposed to that adopted by us. They are the directions from a place towards the first meridian and the Equator. Accordingly Ganesh Daivjna calls all Indian latitudes as southern 'यमाक्षा पलाक्षा'

Tandava Krishnacharya who in his Panchanga for Shaka year 1835 has given the longitude of Vizagapattana from Ujjain as 7 35' 30" West according to the Tûlansha System quotes in support of it the following verse from the Siddhanta Tatvaviveka of Kamalakara

पश्चिमे रोमकाख्याच्च द्विद्वि (२०) भागै पुर किल ।
खाल्दनामिव चास्ति व्यक्षस्थ तद्दत किल ॥ १७२
मेरुद्वयस्थानसक्त रेखावृत्त च यत तत ।
स्वदेशावधि तुलाशा स्पष्टभूपरिधौ स्वता ॥ १७३

209 Here we meet with a clear allusion in Sanskrit to the town Caldai of the Chaldeans is Chaldatta. They were also called the Caldai from the name of the place whence they were supposed to have come originally. The Caldai or Chaldeans are first met with in the 9th century B C as a small tribe on the Persian Gulf whence they moved northward probably taking part in the invasion led successfully by Shalmaneser against the Babylonians in 851 B C (*Vide* Encl Britannica Edn 9 page 136)

This shows the probable connection between the Era of Nabonassar and the Aryan Era as suggested by us (*Vide* Sec 152 *f*) The Encyclopedia also mentions that Tiglath Pileser I captured Babylon in 1130 B C and carried his arms into India. The Aryan Era had been begun in 1193 B C and Tiglath Pileser being convinced of its excellence might have invited the Aryan colony of Chronologers or Caldais to go along with him and settle down on the coast of the Persian Gulf in his dominion

Note 15

210 Additional evidence in support of the theory of the Assyrian origin of the Sûrya Siddhanta

(*a*) The Surya Siddhanta is often quoted in our old works as Saura for instance Saura Mana, Saura Bhashya It must have been its original Assyrian name The Arabic Sur San which begins with the entry of the Sun into the Mriga Nakshatra calculated according to the Surya Siddhanta suggests the same conclusion The cycle of the eclipses called *Saros* which was undoubtedly known to the Chaldeans may be traced to the original name Saura

(*b*) The Shadashitimukha holidays described in Sûrya S° are said to be of Chaldean origin They commence with the entry of the Sun in the sign Libra for which they had peculiar predilection

(*c*) The most significant number of the Kaliyuga years 432000 found in the Assyrian works is an indisputable evidence The seemingly absurd mention in them that 10 kings ruled before the deluge at the rate of 43200 year each can be explained just as we do by giving fictitious names of king to each of the mighty periods called *Manvantaras* In the language of the Assyrian we might say that six Manus ie Swayambhuva, Swarochish Uttama Tamasa Raivata Chakshus have reigned during the past 1972944000 year and that the present king Vaivasvata has been ruling since the beginning of the Kaliyuga In our Sankalpa we daily repeat Vaivasvata Manvantare without any idea of ridicule The number of Kaliyuga years 4 32 000 appears to be of Indian origin and might have been carried with them by the Chaldeans in their migration to the shores of the Persian Gulf

(*d*) Lastly the most convincing evidence in support of the theory is the complete and astonishing agreement between the times of the Eclipses actually observed during the Assyrian ascendancy and the times calculated exclusively with the elements of the Sûrya Siddhanta (that of the moon's node being excepted) without

any correction due to the secular acceleration of the moon's mean motion. Had the elements of the Surya Siddhanta been derived from much later observations there could have been no such agreement.

(e) We may further suggest that the Surya Siddhanta elements and inequalities (*vide* Sec. 40) being most accurately determined twenty five centuries ago, are better fitted to be employed in the calculation of the *ancient eclipses* than the modern ones, in which the co-efficient of the moon's acceleration is still somewhat empirical. Theory gives for it 6″ 0 per century, while the observations assign 8″ 0. (Tables de la lune fondees sur la theorie de Delaunay par Radau.)

NOTE 16

211 Bid, the residence of Bhâskarâcharya.—It is regrettable that the question about the place of residence of so eminent an astronomer as Bhaskaracharya should remain so long unsettled. It has been wrongly identified with Bijapur, Beedar and Patan by scholars like Sudhakara and S. B. Dixit.

The colophon at the end of Goladhyaya says:—

आसीत्सह्यकुलाचलाश्रितपुरे त्रैविद्यविद्वज्जने ।
नानासज्जनधाम्नि विज्जलविडे शाण्डिल्य गोत्रो द्विज ॥
श्रौतस्मार्तविचारसारचतुरो नि शेषविद्यानिधि ।
साधूनामवधिर्महेश्वरकृती दैवज्ञचूडामणि ॥

Mr S. B. Dixit appears to be influenced by the apparent impossibility that Bid, which is about 200 miles to the east of the Sahyadri range, can be said to be in its neighbourhood. On the other hand Bhaskara was no simpleton to speak so loosely and wrongly about the geographical position of his own residence.

The discrepancy is merely apparent and not real. It is due to the failure on the part of Mr. Dixit to mark the broad distinction between the meanings of the words *Achala* and *Kulachala*. The

former is applied to a single range and the latter to the whole family inclusive of the off shoots emanating from the principal range Bhâskara seems to have specially used the word Kúlachala to signify that Bid was situated in the neighbourhood of an off shoot or branch of Sahyadri and so he leaves no ground for mis understanding him The readers will please see on a map that Sahyadri sends out a lengthy off-shoot eastwards near Deolali in the Nasik District It runs 200 miles parallel to the Godavari as far off as Beedar and passes on its way near Bid which is situated in the Nizam s territory on the meridian of Ujjain at 19° Latitude

212 By *Bijjala Bid* is meant that Bid belonged to Bijjala who was a vassal prince of the Western Chalukya king Tailapa II in A D 1150 (see Dr Bhandarkar s early History of the Deccan page 90) which is also the date of the Siddhanta Siromani Munish vara the commentator of his works tells us that Bid was situated not far from the Godâvari Bijapur therefore cannot be the residence of Bhâskara as guessed by Pt Sudhakara of Benares in his Ganaka tarangini Nor was he a Karnataka Brahmin as he uses the Sanskritized pure Marathi word *Pâti* meaning a board sprinkled with fine red dust on which formerly arithmetical calcula tions were made But he also uses the word *Kuttaka* for the method of solving indeterminate equations Kuttaka is derived from the Kanarese root Kuttu meaning to pound or pulverize This opens a new problem for research *viz* whether Algebra had its origin in Karnataka There is some ground to believe that Shridhara and Padmanabha whom he mentions as renowned Algebraists must have lived either in Karnataka or in Kalinga the modern Telugu Districts Aryabhatta (A.D 476) the first of the known Indian Algebraists, was a native of South Canara or Malabar where his Siddhanta is still used His commentator Paramadishvara uses the word Kuttakara in his Bhata Dipika " '*Iti dvividhah kuttakarah niragrassagraschete* page 47 Aryabhatiya edited by Dr H Kern. Leiden A D 1874

CHAPTER XVIII

BIBLIOGRAPHY

213 Early chronologists—In the early half of the eighteenth century Beschi the famous Tamil Scholar and Jesuit missionary in Madura and Walther a Tranquebar missionary, are said to have published in Latin the accounts of the Indian system of chronology But it was not until the beginning of the nineteenth century that systematic attempts were made for the compilation of books based on the correct principles and data of the Hindu Siddhantas

214 Kāla-Sankalita—Under the auspices of the Board of Superintendence of the College of Fort St George Lieut Col John Warren published under the above title a big quarto Volume of over 400 pages on Indian Chronology The date of its dedication is 26th February 1825 Assisted by Adi Shesha Brahmin he has incorporated into it the tables of one Vasudal Couchinna a Telugu author and has closely followed the Surya Siddhanta and the Era of Kali Yuga It contains rules examples and tables for the computations of tithis nakshatras and the positions of the planets

There appears in the Miscellanea of the Indian Antiquary for January 1891 an able article entitled Examination of some errors in Warren's Kala Sankalita contributed by Mr Shankar B Dixit of Poona

215 Graha sâdhanâchin Koshtaken—Under this title Prof Kero Laxuman Chhatre of the Deccan College Poona published in Marathi in A D 1860 his lunar and planetary tables based on those of Burg Delambre and Rev Vince The book begins with chronological rules and tables which are absolutely necessary for the calculation of the Ahargana corresponding to the given tithi of a luni solar calendar With the help of these tables Mr Dixit published in the Indian Antiquary for April 1887 his article on *The method of calculating the week days of the Hindu tithis and the corresponding English dates*

Prof Chhatre deserves great praise for being the first to undertake the calculation of all the Adhika and Kshaya *months* from Shaka year zero to the year 2105 'They have been,' says D B Pillai, 'copied freely by General Cunningham in his Indian Eras and by Mr Patel in his Chronology without any check

216. South Indian Chronological Tables—These were edited by W S Krishnaswami Naidu and Dr Robert Sewell M C S, Madras They have been reviewed by Mr S B Dixit in the Indian Antiquary for October 1890

217. Dr Herman Jacobi, Ph.D.—He has contributed a number of learned articles and tables on Indian Chronology to *Epigraphia Indica* and to *Indian Antiquary*, A D 1888 He has invented a new and easy method of calculating English dates corresponding to the given Indian dates and *vice versa* As he has made use of mean motions, the first results are only approximate, and the second ones require much labour

218 The Indian Calendar.—This has been edited under the joint authorship of Messrs Sewell and Dixit It covers a period of 16 centuries A D 300—1900 It gives for each year the elements of computation for the beginning of the solar as well as of the lunar years But these elements are not of much use as the book contains no means of ready reckoning like that of Mr Pillai The insistence of the method of successive approximation in the calculation of tithis has unfortunately, a deterrent effect on computers who are at times required to repeat the approximations ten or fifteen times in order to obtain the correct result

It contains an extensive and very useful table or Jantri of the Hijari and Christian dates, and another one supplied by Dr Schram of Vienna, containing the dates of all the Solar eclipses visible in India with elements for their computation for a given locality

The letter press and the foot notes contain very useful information and explanations relating to chronological questions

219 The Indian Chronology—It is compiled by Diwan Bahadur S K Pillai of Madras (A D 1911) Of all the books written on Indian Chronology this is the best in point of ease and accuracy The elements are given for every new moon of the past twenty centuries so that with the help of the eve table, the ending moment of any tithi can be obtained correct within a few palas But the calculation of B C dates is not so easy

220 The Jantries—These are ephemerides of concurrent dates of two or more eras included within some historical periods

The Peshwa Period—The late Mr B P Modak professor at the Rajaram College of Kolhapur has published (A D 1889) a very useful Jantri of the simultaneous dates It has greatly facilitated the work of historical research of the Peshwa Period as it contains full details regarding the dates of the Shalivahana Vikrama Râja Shaka Sursan Fasli Hijri and the Christian Eras for Shaka years (1650—1811) or for A D year (1728—1889)

The Maratha Period My friend Mr G S Khare retired Hon Assistant Engineer has recently (A D 1920) presented to the Bharat Itihasa Samshodhaka Mandala of Poona a hundred and fifty year Ephemeris similar in its details to the above Jantri for the Shaka years (1500—1649) or for the A D year (1578—1727) i e from fifty years before the birth of Shivaji to the death of the first Peshwa Balaji Vishvanath Mr Khare could not avail himself of old manuscript almanacs of such distant date He has undertaken and ably carried out in his old age the most fatiguing work with no other desire than to serve his country

In his calculation of the five *eras* he has made use of the Tables of Tithi Chintamani of Ganesha Daivajna

[END OF PART II AND OF THE BOOK]

TABLES

To be used in calculations.

TABLE 1

Summary of Eras

Vide Secs 2 *to* 4

No	Era and kind of year	Began in	Calendar	Year begins with	Where or by whom is used
		B C			
1	Julian Era Cur Trop	—4713 Jan	Solar	January 1	Astronomers
2	Jewish Era Cur Sid	—3761 Sep	L S	Tessera 1	The Jews
3	Kaliyuga exp Sid	—3102 Feb	L S	Chaitra Shukla	The Hindus
4	Chinese Cur Trop	—2637 Feb	L S	No 1 Shukla	The Chinese
5	Saptarshi Cur Sid	—3076 Apr	L S	Chaitra Shukla	Cashmere
6	Vikrama Exp Sid	—58 Nov	L S	Kârtika Shukla	Gujaratha
7	Vikrama Exp Sid	—58 Apr	L S	Chaitra Krishna	Northern India
		A D			
8	Christian Cur Trop	+ 1 Jan	Solar	January 1	The Christians
9	Shaka Era Exp Sid	+ 78 Apr	L S	Chaitra Shukla	The Deccan
10	Chedi Cur Sid	+ 247 Oct	L S	Âshvin Krishna	Not in use
11	Vallabhi Cur Sid	+ 318 Nov	L S	Kârtika Shukla	Kathiawar A D 400 1300
12	Gupta Era Cur Sid	+ 319 Apr	L S	Chaitra Krishna	Central India A D 400 700

Abbreviations —Cur = Current Sid = Sidereal,
Trop = tropical Exp = expired

Note —Years that begin with Shukla paksha are Amanta and those that begin with Krishna-paksha are Purnimanta.

The centuries of the Saptarshi Era are generally omitted as if it were a cycle of 100 years

TABLE I—(contd)

SUMMARY OF ERAS

No	Era and kind of year	Began in	Calendar	Year begins with	Where or by whom used
13	Vilayati, Cur Sid	A D + 592 Sep	Solar	Kanya 1	Orissa
14	Amali Cur Sid	+ 592 Oct	L S	Bhadra, Shu 12	Orissa
15	Bengal San Cur Sid	+ 593 Apr	Solar	Vaishakha 1	Bengal Assam
16	Magi San, Cur Sid	+ 638 Apr	Solar	Do	Chitagong
17	Deccan Fasali Cur Sid	+ 591 June	Solar	Mrigadi	Revenue accounts
18	Sursan or Arabic San, Cur Sid	+ 599 June	Solar	Mrigadi	Was in use during Mahratta Supremacy
19	Hargh Kala Cu Sid	+ 606 Nov			Nepal Not in use now
20	Hijri San, Cur Lunar	+ 622 July	Lunar	Muharam 1	The Musalmans
21	Kollam Era Cur Sid	+ 825 Sep	Solar	Kanya 1	North Malabar
	Do do	Do	Do	Simha 1	South Malabar Kochin Travancore
22	Newar, Exp Sid	+ 879 Nov	L S	Kartika Shukla 1	Nepal 878 to 1768 A D
23	Chalukya, Exp Sid	+1076 Apr	L S	Chaitra Shukla 1	Deccan A D 1079 1162
24	Laxman Sen, Exp Sid	+1118 or +1108 Nov	L S	Kartika Shukla 1	Tirhut Mithila with Shaka Vikrama
25	Raja Shaka, Cur Sid	+1673 June	L S	Jyestha Shu 13	Dates from Shiva ji's coronation
26	Coptic, Cur Trop	+ 284	Solar	August 29	In some part of Egypt

TABLE 2

The Adhika and Kshaya months.

(Part I.)

Calculated on the basis of the Sûrya-Siddhânta by Prof. Kero Laxuman Chhatre

The Intercalary or Adhika months with their Shaka years

Shra	1	Jye	4	Cha	7	Shra	9	Dha	12	Vai	15	Bhā	17
	20		23		26		28		31		34		36
	39		42		*45		47		50		53		55
	58		61		*64		66	Jye	69		72		74
Dha	77		80	Āsh	82		85		88		91		93
	96		99		101		104		107		110		112
	115		118		120		123		126	Cha	129	Shr	132
	134		137		139		142		145		148		150
	153	Vai	156	Bhā	158		161		164		167		169
	172		175		177		180		183		*186		188
	191		194		196		199		202		*205		207
Jye	210		213		215	Dha	218		221	Āsh	223		226
	229		232		234		237		240		242		245
	248		251		253		256		259		261		264
	267	Cha	270	Shr	272		275		278		280	Dha	283
	286	Phā	288		291		294	Vai	297	Bhā	299		302
	305		307		310		313		316		318		321
	*324	Cha	327*		329		332		335		337		340
	343		*346		348	Jye	351		354		356		359
	362	Bhā	364		367		370		373		375		378
	381		383		386		389		392		394		397
	400	Āsh	402		405		408	Cha	411*		413		416
	419		421	Dha	424		427	Phā	429*	Shr	432		435
Vai	438	Bhā	440		443		446		*449		451		454
	457		459		462		465		*467		470		473
	476		478		481		484		*486		489	Jye	492
	495		497		500	Vai	503	Bhā	505		508		511
	514		516		519		522		524		527		530
	*533		535		538		541		543		546		549
Cha	*552		554		557		560		562	Dha	565		568
Kār	570	Shr	573		576		579		581		584		587
	589		592		595	Cha	598		600		603		606
Āsh	608		611		614		617		619		622		625
	627		630	Jye	633		636	Shr	638		641	Vai	644
Bhā	646		649		652		655		657		660		663
	*665		668		671		*674		676		679		682
	684		687		690		*693		695		698		701

Note.—The years marked with an asterisk are preceded by a kshaya month. Dha = Âshâdha Ash = Âshvina

TABLE 2—(*contd*)

(PART I)—*continued*

(*Based on the Surya Siddhânta*)

Adhika months with the years of Shaka Era.													
Bhâ	703	Dha	706	Jye	709	Âsh	711	Sh	714	Dha	717	Vai	720
	722		725		728		730		733		736		739
	741		744		747		749		752		755	Cha	758
Shr	760		763		766		768		771		774		777
	779		782	Vai	785	Bha	787		790	Jye	793		796
	798		801		804		806		809		812		*815
	817		820		823		825		828		831		*834
	836		839		842		844	Dha	847		850	Âsh	853
	855		858		861		863		866		869		871
	874	Jye	877		880		882		885		888		890
	893		896	Cha	899	Shr	901		904		907		909
	912		915		918		920		923	Vai	926	Bha	928
	931		934		937		939		942		945		947
	950		953		956		958		961		964		966
	969		972		*975		977	Jye	980		983		985
Dha	988		991	Âsh	993		996		999		1002		1004
	1007		1010		1012		1015		1018		1021		1023
	1026		1029		1031		1034		1037	Cha	1040		1042
	1045		1048		1050	Dha	1053		1056		1059	Shr	1061
	1064	Vai	1067	Bhâ	1069		107		1075		1078		1080
	1083		1086		1088	Shr	1091		1094		1097		1099
	1102		1105		1107		1110		1113		*1116		1118
	1121		1124		1126	Dha	1129		1132	Âsh	1134		1137
Jye	1140		1143		1145		1148		1151		1153		1156
	1159		1162		1164		1167		1170		1172		1175
	1178	Cha	1181*		1183		1186		1189		1191	Dha	1194
	1197	Pha	1199*	Shr	1202		1205	Vai	1208	Bhâ	1210		1213
	1216		*1218		1221		1224		1227		1229		1232
	1235		*1237		1240		1243		1246		1248		1251
	1254		*1256		1259		1262		1265		1267		1270
Vai	1273	Bhâ	1275		1278	Jye	1281		1284		1286		1289
	1292		1294		1297		1300		*1303		1305		1308
Jye	1311		1313		1316		1319	Cha	1322*		1324		1327
Vai	1330		1332	Dha	1335		1338	Kâr	1340	Shr	1343		1346
	1349		1351		1354		1357		1359		1362		1365
	1368		1370		1373		1376		1378		1381		1384
Cha	1387		1389		1392		1395	Ph	1397*		1400		1403

TABLE 2—(*contd*)

(PART I)—*continued*

(*Based on the Surya Siddhanta*)

Adhika Months with the years of Shaka Era.						
Cha. 1406	Shr 1409	Dha 1411	Vai 1414	Bh 1416	Sh 1419	Jye 1422
1425	1427	1430	1433	1435	1438	1441
Vai 1444*	Bh a 1446	1449	1452	1454	1457	1460
Cha 1463*	Shr 1465	1468	1471	1473	Dha 1476	1479
Ash 1481	1484	1487	1490	1492	1495	1498
1500	1503	1506	1509	1511	1514	1517
1519	1522	1525	Cha 1528	1530	1533	1536
1538	1541	1544	1547	Shr 1549	1552	Vai 1555
Bh a 1557	1560	Jye 1563	1566	1568	1571	1574
1576	1579	1582	1585	1587	1590	1593
1595	1598	1601	1604*	1606	1609	1612
1614	Dh a 1617	1620	Ash 1622	1625	Jye 1628	1631
1633	1636	1639	1641	1644	Dha 1647	1650
1652	1655	1658	1660	1663	1666	Cha 1669
1671	1674	1677	1679	1682	Jye 1685	1688
Shr 1690	1693	Vai 1696	Pha 1698	1701	1704	1707
1709	1712	1715	1717	1720	1723	1726
1728	1731	1734	1736	1739	1742	1745*
1747	1750	1753	1755	Dha 1758	1761	Ash 1763
1766	Jye 1769	1772	1774	1777	1780	1782
1785	1788	1791	1793	1796	1799	1801
1804	1807	Cha 1810	1812	1815	1818	1820
1823	1826	1829	Shr 1831	1834	Vai 1837	Dha 1839
1842	1845	1848	1850	1853	1856	1858
1861	1864	1867	1869	1872	1875	1877
1880	1883	1886*	1888	1891	1894	1896
Dha 1899	1902	[illegible] 1904	1907	Jye 1910	1913	1915
1918	1921	Ash 1923	1926	1929	1932	1934
1937	1940	1942	1945	1948	Cha 1951*	1953
1956	1959	1961	Dha 1964	1967	[illegible] [illegible]	Shr 1972
1975	Vai 1978	[illegible] 1980	1983	1986	1989	1991
1994	1997	1999	2002	2005	[illegible]	2010
2013	2016	2018	2021	2024	[illegible]	2029
2032	2035	2037	2040	Vai 2043	[illegible]	2048
Jye [illegible]	2054	2056	2059	Jye [illegible]	Pha 2064	[illegible]
[illegible]	[illegible]	[illegible]	2078	Vai [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2102	Dha [illegible]

TABLE 2—(*contd.*)

(PART II)

(Based on the Surya Siddhânta)

Kshaya or suppressed months in Shaka years with the Adhika months preceding them

Adhika	Kshaya	Adhika	Kshaya	Adhika	Kshaya
Âsh 44	Kâr 44	Ash 551	Pau 551	Kar 1321	Pau 1321
Âsh 63	Marg 63	Kâr 673	Mâr 673	Âsh 1397	Mâr 1397
Kâr 185	Mâr 185	Âsh 692	Pau 692	Kâr 1443	Mâr 1443
Âsh 204	Mâr 204	Kar 814	Mâr 814	Âsh 1462	Pau 1462
Kâr 326	Mâr 326	Âsh 833	Pau 833	Âsh 1603	Pau 1603
Âsh 345	Pau 345	Âsh 974	Pau 974	Âsh 1744	Pau 1744
Kâr 410	Pau 410	Âsh 1115	Pau 1115	Âsh 1885	Pau 1885
Kâr 429	Mâr 429	Kâr 1180	Pau 1180	Âsh 1904	Mâr 1904
Kâr 448	Pau 448	Kar 1199	Pau 1199	Kâr 1950	Mâr 1950
Kâr 467	Pau 467	Mâr 1218	Pau 1218	Mâr 1969	Pau 1969
Âsh 486	Pau 486	Kâr 1237	Mâr 1237	Kar 2007	Mâr 2007
Kâr 532	Mâr 532	Âsh 1256	Pau 1256	Âsh 2026	Pau 2026
—	—	Kâr 1302	Mâr 1302	Âsh 2045	Pau 2045

TABLE 3

(Based on the Sûrya Siddhânta)

Chronological elements for the Meshâdi of each century of Kaliyuga

Kali yuga Era	Shaka Era B S	Christian Era B C	Tithi Shuddhi (1)	Vâra (2)	Christian Months & Date (3)	Moon's Anomaly (4)	Sun's Anomaly (5)	Precession Ayanâmsh (6)	Râhu (7)
Year	Year	Year	Tithi	Vara	Days	°	280°	°	°
0	3179	3102	27·795	3 579	F 15 579	241 57	60	-59 30	235·18
1	3178	3101	8·860	4·838	15·838	333 77	·60	59 32	254·54
101	3078	3001	5 343	4·714	16·714	183 18	·60	57·73	30·39
201	2978	2901	1·827	4·589	17 589	32 63	60	56 06	166·23
301	2878	2801	28·310	4 465	18·465	242·07	·60	54·39	302·08
401	2778	2701	24·793	4·341	19 341	91·51	·60	-52·82	77·92
501	2678	2601	21·277	4 216	20·216	300 95	60	51 15	213 76
601	2578	2501	17·760	4 092	21 092	150 39	60	49 48	349 61
701	2478	2401	14 243	3 968	21 968	359 83	·60	47·91	125·45
801	2378	2301	10·727	3·843	22 843	209 28	60	46 24	261 29
901	2278	2201	7·210	3 719	23 719	58 72	60	-44·57	37 14
1001	2178	2101	3·693	3 594	F 24 594	268 16	60	43 00	172 98
1101	2078	2001	0·177	3 470	25 470	117 60	60	41 33	308 83
1201	1978	1901	26·660	3 346	26 346	327 01	60	39 66	84 67
1301	1878	1801	23 144	3 221	27 221	176 48	60	38 09	220 61
1401	1778	1701	19 627	3 097	28 097	25 93	·60	-36 42	356·36
1501	1678	1601	16·110	2·973	28·973	235·37	·60	34·75	132·20
1601	1578	1501	12 593	2·848	F 29 848	84·81	·60	33·18	268·04
1701	1478	1401	9 077	2·724	M 1 724	294 25	·60	31·51	43 89
1801	1378	1301	5·560	2 600	2·600	143 69	60	29 84	179·73
1901	1278	1201	2·043	2·475	3·475	353 13	·60	-28 27	315 58
2001	1178	1101	28·527	2·351	4·351	202·58	·60	26·60	91 42
2101	1078	1001	25·010	2 227	5 227	52·02	·60	24 93	227 26
2201	978	901	21·493	2·102	6 102	261·46	·60	23·38	3 11
2301	878	801	17 977	1·978	6·978	110 90	69	21 69	138 95
2401	778	701	14·460	1·854	7·854	320·34	60	-20 02	274 79
2501	678	601	10·993	1·729	M 8 729	169·78	60	-18 45	50 64

TABLE 3—*contd*

(*Based on the Sûrya Siddhanta*)—*contd*

Chronological elements for the Meshâdi of each century of Kaliyuga

Kal yuga Era	Saka Era B S	Christ an Era B C	Tith Shud dhi (1)	Vara Week days (2)	Christian Months Date (3)	Moon's Ano maly (4)	Sun's Ano-maly (5)	Precession or Ayanamsh (6)	Râhu (7)
Year	Year	Year	Tithi	Vâra	M Days	°	280°	°	°
2601	578	501	7 427	1 605	M. 9 605	19 23	60	−16 78	186 48
2701	478	401	3 910	1 481	10 481	228 67	60	15 11	322 33
2801	378	301	0 393	1 356	11 356	78 11	60	13 54	98 17
2901	278	201	26 877	1 282	12 282	287 55	60	11 87	234 01
3001	178	101	23 360	1 107	13 107	136 99	60	10 20	9 86
3101	B 78	B C 1	19 843	0 983	13 983	346 43	60	8 63	145 70
3201	A 22	A 100	16 327	0 859	14 859	195 87	60	6 96	281 55
3301	122	200	12 810	0 734	15 734	45 32	60	5 29	57 39
3401	222	300	9 293	0 610	16 610	254 76	60	−3 72	193 23
3501	32?	400	5 777	0 486	17 486	104 20	60	2 05	329 08
3601	4?2	500	2 260	0 361	18 361	313 64	60	−0 38	104 92
3701	52?	600	28 743	0 237	19 237	163 08	60	+1 19	240 76
3801	6?2	700	25 227	0 113	20 113	12 53	60	? 86	16 61
3901	722	800	?1 710	6 988	20 988	221 97	60	+4 53	152 45
4001	822	900	18 193	6 864	21 864	71 41	60	6 10	288 30
4101	922	1000	14 677	6 740	22 740	280 85	60	7 77	64 14
4201	10?2	1100	11 160	6 615	23 615	130 29	60	9 44	199 98
4301	1122	1?00	7 643	6 491	24 491	339 73	60	11 01	335 83
4401	1222	1300	4 127	6 367	?5 367	189 18	60	+1 68	111 67
4501	1322	1400	0 610	6 242	26 242	38 62	60	14 35	247 51
4?0	1422	1500	27 093	6 118	27 118	248 06	60	15 92	23 36
4 01	1522	1600	23 577	5 993	27 993	99 06	60	17 59	159 20
4801	1622	1700	20 060	5 869	M28 869	308 50	60	19 ?6	295 05
4901	1722	1800	16 543	5 745	A 10 745	157 94	60	+ 0 83	70 89
5001	1822	1900	13 027	5 620	A 12 620	7 39	60	2? 50	?06 73
5101	1922	2000	9 510	5 496	A 13 496	216 8?	60	24 13	342 58
5201	?022	2100	5 993	5 37?	A 15 372	66 26	60	+— 78	118 42

Note—Column (7) contains supplement of the moon's node *plus* 77°26

TABLE 4

(*Sûrya Siddhânta.*)

Increase of Elements in years.

Years.	Tithi. (1)	Vâra. (2)	A D day. (3)	Moon's anomaly. (4)	Sun's anomaly (5)	Precession Ayana (6)	Râhu (7)
Com				°	°	°	°
1	11·065	1·259	259	92 09	0 00	0·02	19·35
2	22·130	2·517	·517	184·19	0·00	03	38 71
3	3 194	3·776	·776	276 28	0·00	·05	58 06
Leap							
4	14·259	5·035	·035	8·38	0·00	·07	77 41
8	28 518	3 070	070	16·76	0 00	·13	154·82
12	12·778	1·105	·105	25·13	0 00	·20	232·23
16	27·037	6 140	·140	33·51	0 00	·27	309·65
20	11 297	4·175	175	41·89	0 00	33	27·06
24	25 556	2 210	210	50·27	0 00	·40	104 47
28	9·815	0 245	245	58·64	0 00	47	181·88
32	24 074	5 280	·280	67·02	0·00	53	259 29
36	8 334	3 315	315	75·40	0 00	60	336·70
40	22·593	1 350	350	83·78	0·00	67	54·11
44	6·852	6 385	385	92·15	0·00	73	131·53
48	21·112	4·420	420	100·53	0 00	80	208·94
52	5 371	2 445	·445	108·91	0 00	87	286·35
56	19 630	0·490	490	117·29	0·00	93	3·76
60	3·890	5 525	525	125·66	0·00	1·00	81·17
64	18·149	3·560	·560	134·04	0·00	1 07	158 58
68	2 408	1 595	·595	142 42	0 00	1 13	236·00
72	16 667	6 630	·630	150 80	0 00	1·20	313 41
76	0 927	4 665	·665	159 17	0 00	1 27	30 82
80	15 186	2·701	701	167 55	0 00	1·33	108·23
84	29 445	0·735	·735	175 93	0 00	1 40	185 64
88	13 705	5 771	·771	184·31	0 00	1·47	263 05
92	27 964	3 806	·806	192·68	0·00	1 53	340 46
96	12 223	1 841	·841	201·06	0·00	1 60	57 88

TABLE 5

(Surya Siddhânta)

Increase of Elements in the interval of Tithis

Tithis	Vâra	Days	☾'s anomaly	☉'s anomaly	Prec es	Râhu	Sun's Motion deg	Sun's Motion Days
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			°	°	°	°	°	°
1	0 984	0 984	12 86	0 97	0 0	0 05	1	1 0
2	1 969	1 969	25·72	1 94	0 0	0 10	-	2 0
3	2 953	2 953	38 58	2 91	0 0	0 15	3	3 0
4	3 937	3 937	51 44	3·88	0 0	0 21	4	4 6
5	4 922	4 922	64 30	4·85	0 0	0 26	5	5 1
6	5 906	5 906	77 16	5 82	0 0	0·31	6	6 1
7	6 890	6 890	90 02	6 79	0 0	0 36	7	7 1
8	0 875	7 875	102 88	7 76	0 0	0 42	8	8 1
9	1 859	8 959	115 74	8 73	0 0	0 47	9	9 1
10	2 844	9 844	128 01	9 70	0 0	0 52	10	10 1
20	5 687	19 687	257 21	19 40	0 0	1 04	20	20 3
30	1 531	29 531	[illegible]5 82	29 11	0 0	1 57	30	30 4
40	4 374	39 374	154 42	38 81	0 0	2 09	40	40 6
50	0 719	49 218	283 03	48 51	0 0	2 61	50	50 7
60	3 061	59 061	51 63	58 21	0 0	3 13	60	60 8
70	5 905	68 905	180 24	67 91	0 0	3 65	70	71 0
80	1 748	78 748	308 84	77 61	0 0	4 18	80	81·1
90	4 592	88 592	77 45	87 32	0 0	4 70	90	91 3
100	0 435	98 435	206 06	97 02	0 0	5 22	100	101 5
200	0 871	196 871	57 11	194 03	0 0	10 44	200	202 9
300	1 306	295 306	258 17	291 05	0 0	15 66	300	304 4

TABLE 6

Sun s Equation in fractions of a day—For Tithis

Argument = Sun s Anomaly

Arg	0°	30°	60°	90°	120°	150°	Arg
Deg.	Day	Day	Day	Day	Day	Day	Deg
0	000	090	155	178	155	090	30
1	003	093	156	·178	·153	087	29
2	·006	095	·159	·178	·152	·085	28
3	·010	·098	159	·178	·150	082	27
4	·013	·101	·160	·177	·148	·079	26
5	·016	·104	·161	·177	·147	·077	25
6	019	106	163	·177	·145	074	24
7	022	·108	·164	·176	143	·071	23
8	025	111	165	176	141	068	22
9	029	113	167	176	139	065	21
10	032	115	168	176	137	062	20
11	035	118	169	175	135	059	19
12	038	120	170	175	133	056	18
13	041	122	171	175	131	053	17
14	044	124	172	174	129	050	16
15	047	127	173	173	127	047	15
16	050	129	174	172	124	044	14
17	053	131	175	171	122	041	13
18	056	133	175	170	120	038	12
19	059	135	175	169	118	035	11
20	062	137	176	168	·115	032	10
21	065	139	176	·166	·113	·029	9
22	068	141	176	165	111	025	8
23	071	143	176	164	109	022	7
24	074	145	177	163	106	019	6
25	077	147	177	161	104	016	5
26	079	149	177	160	101	013	4
27	082	150	178	159	098	010	3
28	085	152	178	158	095	006	2
29	087	153	178	156	093	003	1
30	090	155	178	155	090	000	0
	+ 330	+ 300	+ 270	+ 240	+ 210	+ 180	

TABLE 7

Moon's Equation for Tithis

Argument = Moon's Anomaly.

Arg	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg	Day	Day	Day	Day	Day	Day	Deg
0	000	225	374	412	343	193	30
1	008	231	377	412	339	187	29
2	016	237	380	411	335	181	28
3	024	244	383	410	332	175	27
4	032	250	385	409	328	168	26
5	040	256	388	408	323	162	25
6	048	262	391	406	318	156	24
7	056	268	393	405	314	*150	23
8	064	273	395	404	*309	*144	22
9	072	279	397	402	304	138	21
10	079	285	399	400	300	131	20
11	087	290	401	398	295	125	19
12	095	296	403	396	290	119	18
13	102	301	404	394	285	113	17
14	110	306	406	392	290	106	16
15	117	311	407	390	275	100	15
16	125	317	408	388	270	093	14
17	132	322	409	385	263	087	13
18	140	327	411	382	260	090	12
19	147	331	412	380	255	073	11
20	155	336	413	377	250	067	10
21	162	340	413	374	245	060	9
22	169	344	413	371	239	053	8
23	176	348	414	367	234	046	7
24	184	353	414	364	228	040	6
25	191	356	414	361	222	033	5
26	198	360	414	357	217	027	4
27	204	363	414	354	211	020	3
28	211	367	413	351	205	013	2
29	218	370	413	347	199	006	1
30	225	374	412	343	193	000	0
	— 330	— 300	— 270	— 240	— 210	— 180	

TABLE 8

Moon's Equation for Nakshatras.

Arg. = Moon's Anomaly.

Arg	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg.	Day	Day	Day	Day	Day	Day	Deg
0	·000	·208	346	·382	317	·178	30
1	·007	·214	349	381	·313	·173	29
2	·015	·220	352	·380	·309	·167	28
3	·022	·226	·355	·379	·306	·162	27
4	·029	·231	·358	·378	·302	156	26
5	·036	·237	·360	·377	·298	·151	25
6	·044	·243	·362	376	294	145	24
7	·051	·248	·364	·375	·290	·139	23
8	·059	·253	·366	·373	·286	·133	22
9	·066	·258	·368	·372	282	127	21
10	·073	·264	·370	·371	277	122	20
11	·080	·269	·372	·369	273	·116	19
12	·088	·274	373	367	·269	110	18
13	·095	·279	·375	365	·264	·104	17
14	·102	·283	·376	·363	·260	·098	16
15	·109	·288	377	361	255	092	15
16	·116	·293	378	·359	250	086	14
17	·123	·298	379	357	245	·080	13
18	·130	·302	·380	354	·241	·074	12
19	137	·306	381	351	·236	·068	11
20	143	·310	381	·349	·231	·062	10
21	·150	·314	382	346	·226	·056	9
22	·157	·318	·382	·343	·221	·049	8
23	·163	·322	·383	·340	·216	·043	7
24	·170	·326	·383	·337	·211	·037	6
25	·176	·329	·383	334	·206	·031	5
26	·183	·333	·383	·330	·200	·025	4
27	·189	·336	·383	·327	·195	·019	3
28	·195	·339	·383	324	·189	·012	2
29	·201	·343	382	320	·184	·006	1
30	·208	·346	·382	·317	·178	000	0
	$\overline{330}$	$\overline{300}$	$\overline{270}$	$\overline{240}$	$\overline{210}$	$\overline{180}$	

TABLE 9

Sun's Equation for **Yogas** Arg = ☉'s Anomaly

Arg	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg	Day	Day	Day	Day	Day	Day	Deg
0	000	077	131	153	131	077	30
6	017	091	140	152	124	064	24
12	033	103	146	150	114	048	18
18	048	114	150	146	103	033	12
24	064	124	152	140	091	017	6
30	077	131	153	131	077	000	0
	— 330	— 300	— 270	— 240	— 210	— 150	

TABLE 10

Moon's Equation for **Yogas** Arg = ☾'s Anomaly

Arg	0 +	30 +	60 +	90 +	120° +	150° +	Arg
Deg	Day	Day	Day	Day	Day	Day	Deg
0	000	190	319	355	295	166	30
6	040	222	334	350	274	135	24
12	080	251	347	341	251	102	18
18	119	277	355	329	223	069	12
24	155	300	356	313	197	036	6
30	190	319	355	295	166	000	0
	— 330	— 300	— 270	— 240	— 210	— 180	

Table 11

Days elapsed from March 0 and April 0

To		From March 0	From April 0	To		From March 0	From April 0
April	0	31	0	October	0	214	183
May	0	61	30	November	0	245	214
June	0	92	61	December	0	275	244
July	0	122	91	January	0	306	275
August	0	153	122	February	0	337	306
September	0	184	153	March	0	365	334
				In leap year		366	335

TABLE 12—(*contd.*)

Moon's Modern Equation of Centre for Tithis.

Horizontal Arg. = The Monthly Tithi.
Vert. Arg : = Moon's Anomaly —(12×Monthly Tithis).

Vert Arg.	Entry. The Monthly Tithis. 8	9	10	11	12	13	14	15	
°	Day.	Day	Day	Day	Day	Day.	Day.	Day	°
0	+ 630—	+ 612—	+ 565—	+ 489—	+ 390—	+ ·272—	+ ·140—	—·000+	360
12	604	·571	510	425	318	·196	+ 062—	·078	348
24	·654	508	438	346	·236	·112	—·019+	·154	336
36	·481	·425	·348	·254	·145	+ ·025—	·100	·226	324
48	·388	·325	·246	·154	+ ·048—	—·064+	·178	·290	312
60	·281	·215	·135	+ 045—	—·050+	·151	·249	·343	300
72	·161	+ ·093—	+ ·017—	— 063+	·147	·231	·311	·384	288
84	+ ·034—	—·035+	—·100+	·168	·238	·303	·361	·409	276
96	— 093+	·155	210	267	319	·363	·396	·417	264
108	218	271	316	355	383	406	·412	·405	252
120	335	376	406	426	·434	427	·409	·378	240
132	·437	465	478	476	·459	429	·385	·326	228
144	·522	534	·527	498	·465	·410	·341	·260	216
156	·583	577	551	506	445	·368	·279	·181	204
168	·618	·595	·548	·481	·401	·307	·204	—·092+	192
180	·627	·582	·516	·432	·336	·229	·116	·000	180
192	·603	542	·459	·361	·253	·139	—·023+	+ ·092—	168
204	·554	·475	·380	·272	·155	—·042+	+ ·072—	·179	156
216	·479	·387	·281	·167	—·052+	+ ·060—	·163	·257	144
228	·381	·278	·167	—·054+	+ ·055—	·157	·245	·321	132
240	·267	·158	—·046+	+ ·062—	·162	·247	·316	·367	120
252	·141	—·031+	+ ·079—	·177	·260	·326	·371	·396	108
264	—·009+	+ ·100—	·200	·284	·347	·389	·407	·406	96
276	+ ·125—	·226	·312	·377	·419	·435	·427	·398	84
288	·250	·342	412	455	472	462	·427	·374	72
300	·366	·442	·492	·515	·506	·471	·413	·335	60
312	·465	·524	·554	·552	·521	·462	·381	·288	48
324	·544	·583	·592	568	·515	·435	·336	·222	36
336	·599	·618	·608	563	·490	·394	·279	·152	24
348	·627	·628	·597	·536	·447	·338	·213	·078	12
360	+ ·630—	+ ·612—	+ ·565—	+ ·489—	+ ·390—	+ ·272—	+ ·140—	+ ·000—	0
	22	21	20	19	18	17	16	15	Vert Arg.
	The Monthly Tithis.							Entry.	

Vide remarks made at the bottom of the preceding page.

TABLE 14

(Based on the Arya Siddhanta)

Elements for the Meshadi of Kaliyuga Centuries 3601—5101

Kali years	Shaka years	Kollam years	A D years	Tithi (1)	Vāra (2)	A D month date (3)	☾'s anom (4)	☉'s anom (5)
3601	422	— 325	500	2 283	0 361	M18 361	° 309 13	280° 0
3701	522	225	600	28 753	0 229	19 229	159 03	280·0
3801	622	125	700	25 222	0 097	20·097	8 93	280 0
3901	722	— 25	800	21·691	6·965	20 965	218·83	280·0
4001	822	+ 75	900	18·161	6 833	21 833	68 73	280 0
4101	922	175	1000	14 630	6 701	22 701	278 63	280 0
4201	1022	275	1100	11 100	6 569	23 569	128 53	280 0
4301	1122	375	1200	7 569	6 437	24 437	338 43	280 0
4401	1222	475	1300	4 039	6 306	25 306	188 33	280 0
4501	1322	575	1400	0 508	6 174	26 174	38 23	280 0
4601	1422	675	1500	26 977	6 042	27 042	248 13	280 0
4701	1522	775	1600	23 447	5 910	27 910	98 03	280·0
4801	1622	875	1700	19 916	5 778	28 778	307 93	280 0
4901	1722	975	1800	16 386	5 646	A 10 646	157 83	280 0
5001	1822	1075	1900	12 855	5 514	12 514	7 73	280 0
5101	1922	+1175	2000	9 325	5 382	13 382	217 63	280 0

Note —The Ārya Siddhanta is at present used in Malabār, Cochin Travancore the Tamil Districts and part of South Canara.

TABLE 15

(Based on the Arya Siddhânta)

To be used in the calculation of the Sankrântis and of the Solar Months in Tamil and Malabar districts.

Tamil Solar months	☉ s longi	Malabâr Solar months	Tithi (1)	Vâra (2)	Days (3)	☾ s ano (4)	☉ s ano (5)
Increase of Elements from the moment of Mesha Sankrânti to each of the subsequent Sankrantis							
1 Chittirai	0°	1 Medam	0 000	0 000	0 000	° 0 0	° 0 0
2 Vaikasi	30	2 Edawam	31 416	2 925	30 925	44·0	30 5
3 Ani	60	3 Mithunam	63 317	6 326	62 326	95 2	61 5
4 Adi	90	4 Karkatagam	95 428	2 933	93 933	147 3	92 9
5 Avani	120	5 Chingam	127 397	6 401	125 401	198 4	123 7
6 Purattasi	150	6 Kanni	158 923	2 436	156 436	243 2	154 3
7 Aipasi	180	7 Tulam	189 863	4 892	166 892	281 4	184 4
8 Kartikai	210	8 Vrichikum	220 243	6 796	216 796	312 4	213 9
9 Margali	240	9 Dhanus	250 219	1 304	246 304	337 9	242 9
10 Tai	270	10 Magaram	280 036	2 655	275 655	2 0	271 9
11 Masi	300	11 Kumbham	309 962	4 112	305 112	26 9	300 9
12 Panguni	330	12 Meenam	339 735	5 920	334 920	56 3	330 0
1 Chittirai	0	1 Medam	371 065	1 259	365 259	92 1	0 0

See note below Table 13.

TABLE 16

(*Based on the Brahma Siddhânta*)

Elements for the Meshâdi of Kaliyuga Centuries

3601—5101

Kali years	Shaka years	A D years	Tithi (1)	Vara (2)	A D months (3)	☾'s anom (4)	☉'s anom (5)
3601	422	500	1 357	6 461	Mr 17 461	296° 62	280
3701	522	600	27 816	6 304	18 304	146 58	280
3801	622	700	24 275	6 148	19 148	356 53	280
3901	722	800	20 735	5 992	19 992	206 49	280
4001	822	900	17 194	5 836	20 836	56 44	280
4101	922	1000	13 653	5 679	21 679	266 40	280
4201	1022	1100	10 119	5 523	22 523	116 35	290
4301	1122	1200	6 571	5 367	23 367	326 31	280
4401	1222	1300	3 031	5 211	24 211	176 27	280
4501	1322	1400	29 490	5 054	25 054	26 22	280
4601	1422	1500	25 949	4 898	25 898	236 18	290
4701	1522	1600	22 408	4 742	26 742	80 13	280
4801	1622	1700	18 868	4 585	27 585	296 09	280
4901	1722	1800	15 327	4 429	Ap 9 429	146 04	280
5001	1822	1900	11 787	4 273	11 273	356 00	280
5101	1922	2000	9 246	4 117	12 117	205 96	290

Note —The Brahma Siddhanta is used in Gujarath and Rajaputana

TABLE 17

(Based on the Brahma Siddhanta)

To be used in the calculation of Sankrantis in Gujaratha and Rajaputana

Names of Sankantis	Months	Increase of elements from Mesha Sankranti to each of the succeeding ones					
		☉'s Long	Tithi (1)	Vara (2)	Days (3)	☾'s anom (4)	☉'s anom (5)
Mesha	Chaitra	0°	0 000	0 000	0 000	00° 0	00° 0
Vrsha	Vaishâ	30	31 423	2 932	30 932	44 0	30 5
Mithuna	Jyestha	60	63 336	6 346	62 346	95 5	61 5
Karka	Ashâdha	90	95 464	[illegible] 968	93 968	147 7	92 6
Simha	Shrâvan	120	127 443	6 447	125 447	198 9	123 6
Kanyâ	Bhadra	150	158 974	2 487	156 487	244 5	154 2
Tula	Ashvin	180	189 912	4 941	186 941	282 4	184 2
Vrischika	Kârtika	210	220 284	6 837	216 837	313 0	213 7
Dhanu	Mârga	240	250 213	1 [illegible]98	246 298	337 9	242 7
Makara	Pausha	270	280 043	2 672	275 672	2 [illegible]	271 7
Kumbha	Mâgha	300	309 968	4 118	305 118	26 9	300 7
Mina	Phâlguna	330	339 738	5 9[illegible]3	334 9[illegible]3	56 3	330 0
Mesha	Chaitra	360	371 065	1 [illegible]58	365 [illegible]	9[illegible] 1	360 0

See note below Table 13

TABLE 18

Motion in the interval of Nakshatras and Yogas

Nak R	Vâra.	Days	☾'s anom	yog R	Vâra	Days	☾'s anom	○'s anom
			°				°	°
1	1·012	1·012	13·22	1	0·941	0·941	12·30	0·93
2	2·023	2·023	26·44	2	1·883	1·883	24·60	1·86
3	3·036	3·036	39·66	3	2·824	2·824	36·90	2 78
4	4·048	4·408	52·88	4	3·766	3·766	49·20	3·71
5	5·059	5·059	66·10	5	4·707	4·707	61·50	4·64
6	6·071	6·071	79·32	6	5·649	5·649	73·80	5·57
7	0·083	7·083	92 54	7	6 590	6·590	86·10	6·50
8	1·095	8 095	105 76	8	0 532	7·532	98·40	7 42
9	2·107	9·107	118·98	9	1·473	8 473	110 70	8·35
10	3 119	10 119	132 20	10	2 415	9 415	123 00	9 28
20	6 238	20 238	264·41	20	4·830	18·430	146·00	18 56

Motion of the Elements for days

Days	Tithis	Vara	☾'s anom	○'s anom	☾'s node
			°	°	°
1	1·015869	1	13 065	0 986	0 053
2	2 031738	2	26 130	1 971	106
3	3 047607	3	39 195	2 957	159
4	4 063476	4	52 260	3 942	212
5	5·079345	5	65 325	4 928	265
6	6·095214	6	78 390	5 915	318
7	7·111083	0	91·455	6·899	·371
8	8 126952	1	104·520	7·855	·424
9	9·142821	2	117·585	8·870	·477
10	10·158690	3	130·650	9·856	0·530
20	20 317380	6	261·300	19·710	1·060

Note—The Sun's apogee being considered fixed, the motion of the sun's anomaly may be taken for that of the mean sun

TABLE 19

The Deccan Samvatsaras and the A. D. years concurring with them

The month of Chaitra generally concurs with April

	Centuries	10—11	11	12	12	13	13—14	14	15	15	16	16—17	17	18	18	19
	Samvatsaras	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr
1	Prabhava	87	47	07	67	27	87	47	07	67	27	87	47	07	67	27
2	Vibhava	88	48	08	68	28	88	48	08	68	28	88	48	08	68	28
3	Shukla	89	49	09	69	29	89	49	09	69	29	89	49	09	69	29
4	Pramoda	90	50	10	70	30	90	50	10	70	30	90	50	10	70	30
5	Prajāpati	91	51	11	71	31	91	51	11	71	31	91	51	11	71	31
6	Angiras	92	52	12	72	32	92	52	12	72	32	92	52	12	72	32
7	Shrimukha	93	53	13	73	33	93	53	13	73	33	93	53	13	73	33
8	Bhāva	94	54	14	74	34	94	54	14	74	34	94	54	14	74	34
9	Yuva	95	55	15	75	35	95	55	15	75	35	95	55	15	75	35
10	Dhātri	96	56	16	76	36	96	56	16	76	36	96	56	16	76	36
11	Ishwara	97	57	17	77	37	97	57	17	77	37	97	57	17	77	37
12	Bahudhanya	98	58	18	78	38	98	58	18	78	38	98	58	18	78	38
13	Pramathi	99	59	19	79	39	99	59	19	79	39	99	59	19	79	39
14	Vikrama	00	60	20	80	40	00	60	20	80	40	00	60	20	80	40
15	Vrisha	01	61	21	81	41	01	61	21	81	41	01	61	21	81	41
16	Chitrabhanu	02	62	22	82	42	02	62	22	82	42	02	62	22	82	42
17	Subhānu	03	63	23	83	43	03	63	23	83	43	03	63	23	83	43
18	Tārana	04	64	24	84	44	04	64	24	84	44	04	64	24	84	44
19	Pārthiva	05	65	25	85	45	05	65	25	85	45	05	65	25	85	45
20	Vyaya	06	66	26	86	46	06	66	26	86	46	06	66	26	86	46
21	Sarvajit	07	67	27	87	47	07	67	27	87	47	07	67	27	87	47
22	Sarvadhāri	08	68	28	88	48	08	68	28	88	48	08	68	28	88	48
23	Virodhi	09	69	29	89	49	09	69	29	89	49	09	69	29	89	49
24	Vikriti	10	70	30	90	50	10	70	30	90	50	10	70	30	90	50
25	Khara	11	71	31	91	51	11	71	31	91	51	11	71	31	91	51
26	Nandana	12	72	32	92	52	12	72	32	92	52	12	72	32	92	52
27	Vijaya	13	73	33	93	53	13	73	33	93	53	13	73	33	93	53
28	Jaya	14	74	34	94	54	14	74	34	94	54	14	74	34	94	54
29	Manmatha	15	75	35	95	55	15	75	35	95	55	15	75	35	95	55
30	Durmukha	16	76	36	96	56	16	76	36	96	56	16	76	36	96	56

To find the Samvatsara for a Shaka year add 78 to it and use the sum as argument of this table

TABLE 21

PART A

Elements of the Musulman Calendar

At commencement of	Hijri Era Current			Christian Era Current		
Hijri Era	Cycle	Year	Day	Year	Days	Vara
	1	1	1	622	196	[illegible]

PART B

Increase of Elements for Cycles

	Cycle	Year	Day	Year	Days	Vara
Cycles	1	30	10631	29	40	5
	2	60	21262	58	9	[illegible]
	3	90	31893	87	188	1
	4	120	42524	116	184	6
	5	150	53155	145	230	1
	6	180	63786	174	270	[illegible]
	7	210	7441	204	32	0
	8	240	85048	233	3	5
	9	270	9557	262	49	3
	10	300	106310	291	85	1
	20	600	212620	582	190	2
	30	900	318930	873	285	3
	40	1200	425240	1165	15	4
	50	1500	531550	1456	119	5
	100	3000	1063100	2916	1	3

TABLE 21

PART C.

Increase of Elements for odd years

Hijri Era		Christian Era			Hijri Era		Christian Era		
Years	Days	Years	Days	Vâra	Years	Days	Years	Days	Vara
1	354	0	354	4	16*	5670	15	195	0
2*	709	1	344	2	17	6024	16	184	4
3	1063	2	333	6	18*	6379	17	174	2
4	1417	3	322	3	19	6733	18	163	6
5*	1772	4	312	1	20	7087	19	152	3
6	2626	5	301	5	21*	7442	20	142	1
7*	2481	6	291	3	22	7796	21	191	5
8	2835	7	280	0	23	8150	22	120	2
9	3289	8	269	4	24*	8505	23	110	0
10*	3544	9	259	2	25	8859	24	99	4
11	3898	10	248	6	26*	9214	25	89	2
12	4252	11	237	3	27	9568	26	78	6
13*	4607	12	227	1	28	9922	27	67	3
14	4961	13	216	5	29*	10277	28	57	1
15	5315	14	205	2	30	10631	29	16	5

PART D

Increase of Days to the end of each month

To the end of—	Days	Vara	To the end of—	Days	Vara
1 Muharram	29	1	1 January	30	2
2 Safar	58	[illegible]	2 February	58	2
3 Rabi ul awwal	88	4	3 March	89	5
4 Rabi ul akhir	117	5	4 April	119	0
5 Jumadalawal	147	0	5 May	150	3
6 Jumadalakhir	176	1	6 June	180	5
7 Rajab	206	3	7 July	211	1
8 Shaban	235	4	9 August	242	4
9 Ramjan	265	6	9 September	272	6
10 Shawwal	294	0	10 October	303	2
11 Zil Kad	324	1	11 November	333	4
12 Zil Hijja	353	3	12 December	364	0

N. B.—Years marked with asterisk are Hijri Leap years

TABLE 22

Showing the number of Hijri Month concurring with the Chaitra of the Shaka years

Shak	H	Shak	H	Shak	H	Shak	H	Shak	H	Shak	H	Shak	H
1369	1	1371	2	1374	3	1377	4	1379	5	1382	6	1385	7
1388	8	1390	9	1393	10	1396	11	1398	12	1401	1	1404	2
1407	3	1409	4	1412	5	1415	6	1417	7	1420	8	1423	9
1426	10	1428	11	1431	12	1434	1	1436	2	1439	3	1442	4
1445	5	1447	6	1450	7	1453	8	1455	9	1458	10	1461	11
1464	12	1466	1	1469	2	1472	3	1474	4	1477	5	1480	6
1482	7	1485	8	1488	9	1491	10	1493	11	1496	12	1499	1
1501	2	1504	3	1507	4	1510	5	1512	6	1515	7	1518	8
1520	9	1523	10	1526	11	1529	12	1531	1	1534	2	1537	3
1539	4	1542	5	1545	6	1548	7	1550	8	1553	9	1556	10
1558	11	1561	12	1564	1	1567	2	1569	3	1572	4	1575	5
1577	6	1580	7	1583	8	1586	9	1588	10	1591	11	1594	12
1596	1	1599	2	1602	3	1605	4	1607	5	1610	6	1613	7
1615	8	1618	9	1621	10	1623	11	1626	12	1629	1	1632	
1634	3	1637	4	1640	5	1642	6	1645	7	1648	8	1651	9
1653	10	1656	11	1659	12	1661	1	1664	2	1667	3	1670	4
1672	5	1675	6	1678	7	1680	8	1683	9	1686	10	1689	11
1691	12	1691	1	1697	2	1699	3	1702	4	1705	5	1708	6
1710	7	1713	8	1716	9	1718	10	1721	11	1724	12	1726	1
1729	2	1732	3	1735	4	1737	5	1740	6	1743		1746	8
1748	9	1751	10	1753	11	1756	12	1759	1	1762	2	1764	3
1767	4	1770	5	1773	6	1775	7	1778	8	1781	9	1783	10
1786	11	1789	12	1792	1	1791	2	1797	3	1800	4	1802	5
1805	6	1808	7	1911	8	1813	9	1816	10	1810	11	1821	1
1824	1	1827	2	1830	3	1832	4	1835	5	1838	6	1840	7
1843	8	1846	9	1949	10	1851	11	1854	12	1857	1	1859	2
1862	3	1865	4	1868	5	1870	6	1873	7	1876	8	1878	9
1881	10	1884	11	1887	12	1889	1	1892		1895	3	1897	4
1900	5	1903	6	1905	7	1908	8	1911	9	1914	10	1916	11
1919	12	1922	1	1924	2	1927	3	1930	4	1933	5	1935	6
1938	7	1941	8	1943	9	1946	10	1949	11	1952	12	1954	1
1957	2	1960	3	1962	4	1965	5	1968	6	1970	7	1973	8
1976	9	1979	10	1981	11	1984	12	1987	1	1989	2	1992	3
1995	4	1998	5	2000	6	2003	7	2006	8	2008	9	2011	10
2014	11	2017	12	2019	1	2022	2	2025	3	2027	4	2030	5
2033	6	2036	7	2038	8	2041	9	2044	10	2046	11	2049	12

TABLE 23

Elements of Tithi-Suddhi, A.D. month and date.

For the Meshâdi of Shaka years from 1382—1742 or of A D years from 1460—1820 covering the Mogal and Marâthâ Periods

Shaka Years	Tithi	A D Date	Vara	Shaka Years	Tithi	A D Date	Vara	Shaka Years	Tithi	A D Date	Vara
1382	4·5	M26·8	4	1502	12·3	M27·8	1	1622	20·1	M28·9	[illegible]
85	18·7	26·8	2	06	26·5	27·9	6	26	4·3	28·9	1
90	3·0	26·8	0	10	10·8	27·9	4	30	18·6	28·9	[illegible]
94	17·3	26·9	5	14	25·1	27·9	2	34	2·8	29·0	6
98	1·5	26·9	3	18	9·3	28·0	0	38	17·1	29·0	[illegible]
1402	15·8	26·9	1	22	23·6	28·0	5	42	1·4	29·0	[illegible]
06	0·1	27·0	6	26	7·8	28·0	3	46	15·6	29·1	[illegible]
10	14·4	27·0	4	30	22·1	28·1	2	50	29·9	29·1	[illegible]
14	28·6	27·0	3	34	6·4	28·1	0	54	14·2	29·1	[illegible]
18	12·8	27·0	1	38	20·6	28·1	5	58	28·4	29·2	[illegible]
1422	27·1	M27·1	6	1542	4·9	M28·2	3	1662	12·7	M29·2	0
26	11·4	27·2	4	46	19·1	28·2	1	66	27·0	29·3	[illegible]
30	25·6	27·2	2	50	3·4	28·2	6	70	11·2	29·3	3
34	9·9	27·2	0	54	17·7	28·3	4	74	25·5	29·3	1
38	21·1	27·3	5	58	1·9	28·3	2	78	9·7	A 9·4	6
42	8·4	27·3	3	62	16·2	28·3	0	82	24·0	9·4	4
46	22·7	27·3	1	66	0·4	28·4	5	86	8·4	9·4	2
50	6·9	27·4	6	70	14·7	28·4	3	90	22·5	9·5	0
54	21·2	27·4	4	74	28·9	28·4	1	94	6·8	9·5	5
1458	5·4	27·4	2	78	13·2	28·5	6	98	21·0	9·5	1
1462	19·7	M27·5	0	1582	27·5	M28·5	4	1702	5·3	A 9·6	1
66	4·0	27·5	5	86	11·7	28·6	2	06	19·6	9·6	6
70	18·2	27·5	3	90	26·0	28·6	0	10	3·8	9·6	4
74	2·5	27·6	1	94	10·2	28·6	5	14	18·1	9·7	2
78	16·7	27·6	6	98	24·5	28·7	3	18	2·3	9·7	0
82	1·0	27·6	4	1602	8·8	28·7	1	22	16·6	10·7	5
86	15·2	27·7	2	06	23·0	28·7	6	26	0·9	10·8	4
90	29·5	27·7	0	10	7·3	28·8	4	30	15·1	10·8	1
94	13·8	27·7	5	14	21·5	28·8	2	34	29·4	10·8	5
98	28·0	27·8	3	18	5·8	28·8	0	38	13·6	10·9	3
1502	12·3	M27·8	1	1622	20·1	M28·9	5	1742	27·9	A 10·9	1
Increase		for		[illegible]				years			
1	11·1	0·3	1	2	22·1	0·5	2	3	3·[illegible]	0·[illegible]	2

Note—The fractions of the date to be attached to the integral vâra. (Vide Section 139, Example 3).

TABLE 24

Perpetual Almanac for Christian Calendar

Indexes	1	2	3	4	5	6	0
B C Centuries	3001 2301 1601 901 01	3101 2401 1701 1001 301	3201 2501 1801 1101 401	3301 2601 1901 1201 501	3401 2701 2001 1301 601	3501 2801 2101 1401 701 1	3601 2901 2201 1501 801 101
A D Centuries	500	400	300	200	100		
(Old Style)	1200	1100	1000 1700	900 1600	800 1500	700 1400	600 1300
(New Style)	1600 2000	1900 2300		1800 2200		1700 2100	
Odd years	1 7 12 18 29 35 40 46 57 63 68 74 85 91 96	2 13 19 24 30 41 47 52 58 69 75 80 86 97	3 8 14 25 31 36 42 53 59 64 70 81 87 92 98	9 15 20 26 37 43 48 54 65 71 76 82 93 99	4 10 21 27 32 38 49 55 60 66 77 83 88 94	5 11 16 22 33 39 44 50 61 67 72 78 89 95	6 17 23 28 34 45 51 56 62 73 79 84 90
Months in a common year	Aug 0	Feb 0 Mar 0 Nov 0	June 0	Sep 0 Dec 0	Apr 0 July 0	Jan 0 Oct 0	May 0
In a leap year	Feb 0				Jan 0		

TABLE 25.

Moon's true daily motion (v) and diameter (*d*) Arg :— ☾'s anomaly.

Arg. deg	0°		30°		60°		90°		120°		150°		Arg. deg.
	(v)	(d)	(v)	(d)	(v)	(d)	(v)	(d)	(v)	(d)	(v)	(d)	
	′	′	′	′	′	′	′	′	′	′	′	′	
0	722	30·0	735	30·0	757	30·5	791	31·2	824	32·0	847	32·3	30
1	723		735		758		792		825		847		29
2	723		736		759		793		826		848		28
3	723		736		760		794		827		848		27
4	723		737		761		796		827		849		26
5	724		738		762		797		828		849		25
6	724		738		763		798		829		850		24
7	724		739		764		799		830		850		23
8	725		740		765		800		831		851		22
9	725		740		766		802		832		851		21
10	725	30·0	741	30·2	767	30·8	803	31·4	833	32·0	852	32·4	20
11	726		742		768		804		833		852		19
12	726		742		769		805		834		853		18
13	726		743		770		806		835		853		17
14	727		744		771		807		836		854		16
15	727		745		773		808		836		854		15
16	728		745		774		810		837		854		14
17	728		746		775		811		838		855		13
18	728		747		776		812		839		855		12
19	729		748		777		813		839		856		11
20	729	30·0	749	30·4	778	31·0	814	31·7	840	32·2	856	32·5	10
21	730		749		779		815		841		856		9
22	730		750		781		816		841		857		8
23	731		751		782		817		842		857		7
24	731		752		783		818		843		857		6
25	732		753		784		819		843		857		5
26	732		754		785		820		844		858		4
27	733		755		787		821		845		859		3
28	733		755		788		822		845		858		2
29	734		756		789		823		846		859		1
30	735	30·0	757	30·5	791	31·2	824	32·0	847	32·3	859	32·5	0
	330°		300°		270°		240°		210°		180°		

TABLE 26

Moon's Diameter (a) and (b), Arg = v, (Vide Sec 165)

Arg v	Dia	(a)	(b)	Arg v	Dia	(a)	(b)	Arg v	Dia	(a)	(b)
720	29 8	54 7	24	770	30 8	57 0	25	820	31 8	59 5	27
730	30 0	55 2	24	780	31·0	57·6	26	830	32 0	60·0	27
740	30 2	55·6	24	790	31·2	58·0	26	840	32 2	60 4	27
750	30 4	56 1	25	800	31·4	58 5	26	850	32·4	60 9	27
760	30 6	56 6	25	810	31·6	58 9	26	860	32 6	61·4	28
770	30 8	57 0	25	820	31 8	59 5	27	870	32 8	61 8	28

TABLE 27

Moon's Latitude

Arg = D in a solar Eclipse, Vide Sec 163 165

Arg = D + 180° in a lunar Eclipse

Argument														
	−	348	349°	350	351	352°	353	354	355°	356°	357°	358°	359°	360°
	+	12	11	10	9	8	7	6	5	4	3	2	1	0
	+	168	169	170	171	172	173	174	175	176	177	178	179	180
	−	192	191	190	189	188	187	186	185	184	183	182	181	180
Lat		60	4 55 5	50 5	45 4	40′ 4	35 5	30 4	25 3	20 3	15 1	10 2	5 1	0

TABLE 28

Semiduration of ☾'s Eclipse Arg = (a) and (a−l) Sec 165

(Argument) (a−l)	Argument (a)								
	54	55	56	57	58	59	60	61	62
′	Pal	Pal	Pal	Pal	Pal	Pal	Pal	Pal	Pal
5	122	119	117	115	113	110	108	106	104
10	171	167	164	161	158	155	152	149	147
15	200	197	193	189	184	182	179	176	173
20	225	221	217	213	208	205	201	198	195
25	241	240	235	231	227	223	219	216	213
30	260	255	250	246	242	238	234	231	227
35	272	267	262	257	253	250	246	242	[illegible]
40	280	276	272	267	263	259	255	252	348
45	286	282	278	274	269	264	262	259	256
50	289	285	281	278	274	270	267	264	261

TABLE 29

Approximate Ghati of the middle of a Solar Eclipse

Arg The Ghati of New Moon

Arg	Mid	Arg	Mid	Arg	Mid	Arg	Mid	Arg	Mid	Arg	Mid
gh	gh	gh	gh	gh	gh	gh	gh	gh	gh	gh	gh
0	56	5	1	10	6	15	15	20	24	25	29
1	57	6	2	11	8	16	17	21	25	26	30
2	58	7	3	12	9	17	19	22	26	27	31
3	59	8	4	13	11	18	21	23	27	28	32
4	60	9	5	14	13	19	22	24	28	29	33
5	1	10	6	15	15	20	24	25	29	30	34

TABLE 30

Nati or Parallax in the Moon's Latitude

Arg:—Sidereal Time T, and the latitude of the place

Arg. T		Degrees of North Latitude							
gh	gh	5°	10°	15°	20°	25°	30°	35°	40°
0	60	—27	—31	—35	—39	—42	—46	—48	—51
3	57	26	30	34	38	42	45	48	50
6	54	23	28	31	35	39	42	45	47
9	51	19	22	27	30	34	37	41	44
12	48	12	16	20	24	28	32	36	40
15	45	— 3	9	14	17	22	26	30	34
18	42	+2	—2	7	11	15	20	24	28
21	39	9	+4	—1	5	10	15	19	23
24	36	14	9	+4	—1	5	10	15	20
27	33	17	12	7	+3	2	7	12	17
30	30	+18	+17	+8	+3	—2	—7	—12	—17

TABLE 31

Sun's Equation of the Centre   Arg. = ☉'s anomaly.

Arg	0 —	30° —	60° —	90° —	120° —	150° —	Arg
Deg	′	′	′	′	′	′	Deg
0	0′·0	65′·6	113′·2	130′·7	113′·2	65′·6	30
1	2·3	67·5	114·3	130·7	112·0	63·6	29
2	4·7	69·5	115·4	130·7	110·8	61·6	28
3	7·0	71·4	116·4	130·6	109·6	59·6	27
4	9·3	73·3	117·5	130·4	108·3	57·6	26
5	11·6	75·1	118·5	130·2	107·0	55·5	25
6	13·9	77·0	119·4	130·0	105·7	53·5	24
7	16·2	78·8	120·3	129·8	104·4	51·4	23
8	18·5	80·6	121·2	129·5	103·0	49·3	22
9	20·8	82·4	122·0	129·1	101·6	47·2	21
10	23·0	84·1	122·8	128·7	100·1	45·0	20
11	25·3	85·9	123·6	128·3	98·6	42·9	19
12	27·5	87·5	124·3	127·9	97·1	40·7	18
13	29·8	89·2	125·0	127·4	95·6	38·6	17
14	32·0	90·8	125·7	126·8	94·0	36·4	16
15	34·2	92·5	126·3	126·3	92·5	34·2	15
16	36·4	94·0	126·8	125·7	90·8	32·0	14
17	38·6	95·6	127·4	125·0	89·2	29·8	13
18	40·7	97·1	127·9	124·3	87·5	27·5	12
19	42·9	98·6	128·3	123·6	85·9	25·3	11
20	45·0	100·1	128·7	122·8	84·1	23·0	10
21	47·2	101·6	129·1	122·0	82·4	20·8	9
22	49·3	103·0	129·5	121·2	80·6	18·5	8
23	51·4	104·4	129·8	120·3	78·8	16·2	7
24	53·5	105·7	130·0	119·4	77·0	13·9	6
25	55·5	107·0	130·2	118·5	75·1	11·6	5
26	57·6	108·3	130·4	117·5	73·3	9·3	4
27	59·6	109·6	130·6	116·4	71·4	7·0	3
28	61·6	110·8	130·7	115·4	69·5	4·7	2
29	63·6	112·0	130·7	114·3	67·5	2·3	1
30	65·6	113·2	130·7	113·2	65·6	0·0	0
Arg.	+ 330°	+ 300°	+ 270°	+ 240°	+ 210°	+ 180°	Arg

TABLE 32

Moon's equation of the Centre Arg= ☾'s anomaly

Arg	0	30°	60°	90°	120°	150°	Arg
Deg	′	′	′	′	′	′	Deg
0	0·0	150·7	260·9	301·7	260·9	150·7	30
1	5·4	155·2	263·4	301·6	258·2	146·2	29
2	10·7	159·7	266·0	301·5	254·4	141·6	28
3	16·0	164·1	268·4	301·3	252·6	137·0	27
4	21·3	168·5	270·8	300·9	249·7	132·3	26
5	26·6	172·8	273·1	300·5	246·7	127·6	25
6	31·9	177·1	275·3	300·0	243·6	122·8	24
7	37·1	181·2	277·4	299·4	240·6	118·0	23
8	42·4	185·4	279·4	298·7	237·5	113·2	22
9	47·6	189·5	281·4	297·8	234·3	108·3	21
10	52·8	193·5	283·3	297·0	230·9	103·4	20
11	58·0	197·5	285·1	296·1	227·4	98·5	19
12	63·1	201·4	286·7	295·1	223·9	93·5	18
13	68·1	205·3	288·1	293·8	220·4	88·5	17
14	73·4	209·1	289·5	292·4	216·7	83·5	16
15	78·5	212·9	291·0	291·0	212·9	78·5	15
16	83·5	216·7	292·4	289·5	209·1	73·4	14
17	88·5	220·4	293·8	288·1	205·3	68·1	13
18	93·5	223·9	295·1	286·7	201·4	63·1	12
19	98·5	227·4	296·1	285·1	197·5	58·0	11
20	103·4	230·9	297·0	283·3	193·5	52·8	10
21	108·3	234·3	297·8	281·4	189·5	47·6	9
22	113·2	237·5	298·7	279·4	185·4	42·4	8
23	118·0	240·6	299·4	277·4	181·2	37·1	7
24	122·8	243·6	300·0	275·3	177·1	31·9	6
25	127·6	246·7	300·5	273·1	172·8	26·6	5
26	132·3	249·7	300·9	270·8	168·5	21·3	4
27	137·0	252·6	301·3	268·4	164·1	16·0	3
28	141·6	254·4	301·5	266·0	159·7	10·7	2
29	146·2	258·2	301·6	263·4	155·2	5·4	1
30	150·7	260·9	301·7	260·9	150·7	0·0	0
Arg.	+330°	+300°	+270°	+240°	+210°	+180°	Arg

TABLE 33

For Charakâla, use Arg =Sun's Tropical longitude

,, Udayântara, use Arg =2 (Sun's Tropical longitude)

,, Bhujântara, use Arg =Sun's anomaly.

Arg.	0° +	30° +	60° +	90° +	120° +	150° +	Arg
Deg	Palas	Palas	Palas	Palas	Palas	Palas	Deg
0	0·00	9·69	17·53	20·71	17·53	9·69	30
1	0·32	9·99	17·71	20·69	17·32	9·37	29
2	0·65	10·29	17·89	20·67	17·11	9·07	28
3	0·97	10·59	18·07	20·65	16·90	8·75	27
4	1·30	10·89	18·25	20·62	16·69	8·41	26
5	1·62	11·19	18·43	20·60	16·48	8·13	25
6	1·95	11·48	18·62	20·57	16·26	7·82	24
7	2·28	11·76	18·77	20·50	16·02	7·50	23
8	2·63	12·05	18·92	20·41	15·77	7·19	22
9	2·96	12·33	19·07	20·37	15·52	6·87	21
10	3·29	12·62	19·22	20·31	15·27	6·55	20
11	3·63	12·90	19·37	20·24	15·02	6·24	19
12	3·95	13·19	19·52	20·18	14·77	5·92	18
13	4·28	13·45	19·63	20·07	14·50	5·60	17
14	4·61	13·71	19·74	19·96	14·24	5·27	16
15	4·95	13·98	19·85	19·85	13·98	4·95	15
16	5·27	14·24	19·96	19·74	13·71	4·61	14
17	5·60	14·50	20·07	19·63	13·45	4·28	13
18	5·92	14·77	20·18	19·52	13·19	3·95	12
19	6·24	15·02	20·24	19·37	12·90	3·63	11
20	6·55	15·27	20·31	19·22	12·62	3·29	10
21	6·87	15·52	20·37	19·07	12·33	2·96	9
22	7·19	15·77	20·44	18·92	12·05	2·63	8
23	7·50	16·02	20·50	18·77	11·76	2·28	7
24	7·82	16·26	20·57	18·62	11·49	1·95	6
25	8·13	16·48	20·60	18·43	11·19	1·62	5
26	8·41	16·69	20·62	18·25	10·89	1·30	4
27	8·75	16·90	20·65	18·07	10·59	0·97	3
28	9·07	17·11	20·67	17·89	10·29	0·65	2
29	9·37	17·32	20·69	17·71	9·99	0·32	1
30	9·69	17·53	20·71	17·53	9·69	0·00	0
Arg	− 330°	− 300°	− 270°	− 240°	− 210°	− 180°	Arg

TABLE 34

The Equinoxial Shadow in digits

Argument = Latitude of Place.

Latitude	Digits	Latitude	Digits	Latitude	Digits
0°	0·00	15°	3·22	30°	6·93
1	0·21	16	3·44	31	7·21
2	0·42	17	3·67	32	7·50
3	0·63	18	3·90	33	7·79
4	0·84	19	4·13	34	8·09
5	1·05	20	4·37	35	8·40
6	1·25	21	4·61	36	8·72
7	1·47	22	4·85	37	9·04
8	1·68	23	5·09	38	9·37
9	1·90	24	5·34	39	9·72
10	2·11	25	5·59	40	10·07
11	2·33	26	5·85	41	10·43
12	2·55	27	6·11	42	10·80
13	2·77	28	6·39	43	11·19
14	2·99	29	6·65	44	11·59
15	3·22	30	6·93	45	12·00

TABLE 35

Semiduration of total phase in lunar eclipse.

Arguments = b and $(b-l)$

	b				
(b—l)	24	25	26	27	28
′	Palas.	Palas	Palas	Palas	Palas
2	52	50	48	47	46
4	72	69	67	65	63
8	95	92	90	88	86
12	111	108	106	103	101
16	121	118	116	113	111
20	127	124	122	120	118
24	128	127	124	124	122
28	—	—	125	124	125

TABLE 36

Lagna and Sidereal Time.

For Lagna, Arg:=Latitude and Sidereal Time.

For Siderеral Time, Arg.=Latitude and Lagna

Arg Side real	North Latitude 0°	5°	10°	15°	20°	25°	30°	35°
Ghati	Lagna	Lagna	Lagna.	Lagna	Lagra	Lagna	Lagna.	Lagna.
	°	°	°	°	°	°	°	°
0	337·5	337·5	337·5	337·5	337·5	337·5	337·5	337·5
1	344·0	344·0	344·0	344·9	345·2	345·8	346·5	346·9
2	350·5	351·0	351·6	352·2	352·9	353·7	354·8	356·1
3	357·0	357·7	358·6	359·5	0·5	1·7	3·2	5·0
4	3·4	4·4	5·6	6·6	8·0	9·4	11·3	13·5
5	9·7	10·9	12·1	13·5	15·1	16·9	19·0	21·6
6	15·9	17·2	18·7	20·3	22·1	24·1	26·4	29·2
7	22·0	23·5	25·1	26·8	28·8	31·1	33·5	36·4
8	27·9	29·6	31·3	33·2	35·2	37·6	40·2	43·2
9	33·8	35·5	37·5	39·4	41·5	43·9	46·6	49·6
10	39·6	41·4	43·3	45·4	47·6	50·0	52·7	55·9
11	45·3	47·2	49·2	51·2	53·5	55·9	58·6	61·6
12	50·9	52·8	54·9	57·0	59·2	61·6	64·3	67·2
13	56·5	58·4	60·5	62·6	64·8	67·2	69·8	72·6
14	62·0	64·0	66·1	68·2	70·3	72·7	75·2	77·9
15	67·5	69·5	71·5	73·6	75·7	78·0	80·8	83·1
16	73·0	75·0	77·0	79·0	81·1	83·1	85·6	88·8
17	78·5	80·5	82·4	84·4	86·4	88·5	90·8	93·1
18	81·7	86·0	87·9	89·8	91·8	93·8	95·9	98·1
19	89·1	91·5	93·4	95·2	97·0	98·9	100·9	103·0
20	95·4	97·2	99·0	100·6	102·4	104·1	106·0	107·9
21	101·2	102·9	104·5	105·9	107·7	109·4	111·0	112·8
22	107·1	108·6	110·1	111·6	113·1	114·6	116·1	117·7
23	113·0	114·5	115·9	117·2	118·5	119·8	121·2	122·6
24	119·1	120·4	121·6	122·8	124·0	125·1	126·3	127·6
25	125·3	126·4	127·5	128·5	129·5	130·4	131·5	132·5
26	131·6	132·5	133·4	134·1	135·0	135·8	136·6	137·5
27	138·0	138·7	139·4	140·0	140·6	141·2	141·8	142·5
28	144·5	144·9	145·4	145·8	146·2	146·6	147·0	147·5
29	151·0	151·2	151·4	151·6	151·9	152·1	152·3	152·5
30	157·5	157·5	157·5	157·5	157·5	157·5	157·5	157·5

TABLE 36—(contd)

Lagna and Sidereal Time

For Lagna ; Arg =Latitude and Sidereal Time

For Sidereal Time ; Arg =Latitude and Lagna

Arg Sidereal	North Latitude							
	0°	5°	10°	15°	20°	25°	30°	35°
Ghati	Lagna	Lagna	Lagna	Lagna	Lagna	Lagna	Lagna	Lagna
	°	°	°	°	°	°	°	°
30	157·5	157·5	157·5	157·5	157·5	157·5	157·5	157·5
31	164·0	163·8	163 6	163·4	163 1	162·9	162·7	162·5
32	170·5	170·1	169·7	169·2	168·8	168·4	168·0	167·5
33	177·0	176·3	175·6	175·0	174·4	173·8	173·2	172·5
34	183·4	182·5	181·6	180·9	180·0	179·2	178·4	177·5
35	189·7	188·6	187·5	186·5	185·5	184·6	183·5	182·5
36	195·9	194·6	193·4	192·2	191·0	189·9	188·7	187·4
37	202 0	200·5	199·1	197·8	196·5	195·2	193·8	192·4
38	207·9	206·4	204·9	203·4	201·9	200·4	198·9	197·3
39	213·8	212·1	210·5	209·1	207·3	205·6	204·0	202·2
40	219·6	217·8	216·1	214·4	212·6	210·9	209·0	207·1
41	225·3	223·5	221·6	219·8	218·0	216·1	214·1	211·9
42	230·8	229·0	227·1	225·2	223·2	221·2	219·1	216·9
43	236·5	234·5	232·6	230·0	228·6	226·5	224·2	221·9
44	242·0	240·0	238·0	236·0	233·9	231·7	229·4	226·9
45	247·5	245·5	243·5	241·4	239·3	237·0	234·2	231·8
46	253·0	251·0	248·9	246·8	244·7	242·3	239·8	236·8
47	258 5	256·6	254·5	252·4	250·2	247·8	245·2	242·4
48	264·1	262·2	260·1	259·0	255·8	253·4	250·7	247·2
49	269·7	267·8	265·8	263·8	261·5	259·1	256·4	253·4
50	275·4	273·6	271·7	269·6	267·4	265·0	262·3	259·8
51	281·2	279·5	277·7	275·6	273·5	271·1	268·4	265·6
52	287·1	265·4	283·7	281·8	279·8	277·4	274·8	271·4
53	293·0	291·5	289·9	288·2	286·1	284·1	281·5	278·5
54	299·1	297·8	296·3	294·7	293·0	290·9	288·6	285·1
55	305·3	304·1	302·9	301·5	300·0	299·1	296·0	293·9
56	311·6	310·7	309·6	308·4	307·1	305·6	303·7	301·0
57	318·0	317 3	316·4	315·5	314·5	313·3	311·8	310·0
58	324·5	324·0	323·4	322·8	322·1	321·2	320·2	319·0
59	331·0	330·7	330·4	330·1	329·8	329·2	328·8	328·3
60	337·5	337·5	337·5	337·5	337·5	337·5	337·5	337·5

TABLE 37

The Constants

Elements	Surya S°	Arya S°.	Brahma S°
In a Mahâyuga of 4320000 yrs	Revolutions	Revolutions	Revolutions.
Days	1577 917 828	1577 917 500	1577 916 450
Suns	4 320 000	4 320 000	4 320 000
Moon's	57 753 336	57 753 336	57 753 300
Apogee of moon	488 203	488 219	488 106
Jupiter s	364 220	364 224	364 226
In a year			
☾ s Anomaly	13 25 581 782	13 25 581 442	13·25 583 218
Tithis	371 06 483 333	371·06 483 333	371·06 458 333
Days	365 25 875 648	365·25 868 055	365·25 843 750
The period of the	Days	Days	Days,
Lunar Month	29 53 058 795	29·53 059 250	29·53 058 790
Anom Month	27·55 459 990	27·55 460 187	27·55 454 648
Sidereal Month	27 32 167 416	27 32 166 848	27·32 166 731
Mean Longitude (by S B Dixit)	499 March 21·25	499 March 21·25	499 March 21·25
Sun ..	s 11 29° 58 42"	s 0 0° 0 0"	s 0 0° 51' 45"
Sun's apogee	2 17 15 0	2 18 0 0	2 17 54 0
Moon ..	9 10 49 33	9 10 45 0	9 11 31 46
Moon s apogee	1 0 53 51	1 5 42 0	1 7 21 3
Greatest Equation of Centre			
Sun s .	2 10 30	2 6 55	2 10 30
Moon s .	5 2 24	5 0 48	5 1 45

TABLE 38

Showing the years of other Eras, concurrent with the year A D 1000

Eras	Chaitra Mesha April A D 1000	Jyestha Mithu June A D 1000	Bhâdra Kanyâ Sept A D 1000	Ashvin Tula Oct A D 1000	Kârti Vrischika Nov A D 1000	Year Begins with
	Year	Year	Year	Year	Year	Year
1 Kali yuga	4101	4101	4101	4101	4101	Shukla
2 Saptarshi	*4076	4076	4076	4076	4076	Do
3 Vikrama North	1057	1057	1057	1057	1057	Krishna
4 Shaka	922	922	922	922	922	Shukla
5 Gupta	681	681	681	681	681	Krishna
6 Magi	362	362	362	362	362	Mesha
7 Bengal San	407	407	407	407	407	Mesha
8 Harshakâla	394	394	394	394	394	Mesha
9 Chalukya	—76	—76	—76	—76	—76	Shukla
10 Deh Fasali	409	410	410	410	410	Mrigâdi
11 Arabi San	400	401	401	401	401	Do
12 Râja Shaka	—674	—673	—673	—673	—673	Shukla
13 Coptic	716	716	717	717	717	September
14 Amali	407	407	408	408	408	Shukla
15 Vilayati	407	407	408	408	408	Kanyâ
16 Kollam	175	175	176	176	176	Kanyâ
17 Chedi Kalchuri	752	752	752	753	753	Krishna
18 Jewish Era	4760	4760	4760	4761	4761	Shukla
19 Vikram South	1056	1056	1056	1056	1057	Shukla
20 Vallabhi	681	681	681	681	682	Krishna
21 Nevar	120	120	120	120	121	Krishna
22 Laxman Sen	—119	—119	—119	—119	—118	Do
or	—109	—109	—109	—109	—108	Do
23 Julian	5713	5713	5713	5713	5713	January
24 Chinese	3637	3637	3637	3637	3637	Magha Sl
25 Hijari	Vide	See	(135)	Year	lunar	Muharram

Note—(1) The year of the above eras concurring with any given A D year other than 1000 can be obtained by simply correcting the above years by its defect under or excess over A D 1000 taking care to lessen the defect by unity in the case of the B C years Vide Sec 145

(2) The vertical thick lines mark the change of years

TABLE 39

Supplementary to Table 5

(*Based on the Surya Siddhānta*)

Increase of Elements to be used in verification

Tithi	Vāra	Days	☾'s anom	☉'s anom	Tithi	Vāra	Day	☾'s anom	☉'s anom
11	3 83	10 83	141 5	10 7	21	6 6	20 6	270 0	0 4
12	4 81	11 81	154 3	11 6	22	0 66	21 66	283 9	21 3
13	5 80	12 80	167 2	12 6	23	1 64	22 64	295 8	22 3
14	6 78	13 78	180 0	13 6	24	2 62	23 62	308 6	23 3
15	0 76	14 76	192 9	14 6	25	3 61	24 61	321 5	24 -
16	1 75	15 5	205 8	15	26	4 59	25 59	334 4	25 2
17	2 73	16 73	218 6	16 5	27	5 58	26 58	34 2	26 2
18	3 72	17 7	231 5	17 5	28	6 56	27 56	360 1	27 2
19	4 70	18 70	244 3	18 4	29	0 55	28 55	12 9	28 1
20	5 69	19 69	257 2	19 4	30	1 53	29 53	25 8	29 1

TABLE 40

For conversion of fractions of a Day into Ghatis and Palas

Centimes	0		1		2		3		4		5		6		7		8		9	
	g	p	g	p	g	p	g	p	g	p	g	p	g	p	g	p	g	p	g	p
00	0	0	0	36	1	12	1	48	2	24	3	0	3	36	4	12	4	48	5	24
10	6	0	6	36	7	12		48	8	24	9	0	9	36	10	12	10	48	11	24
20	12	0	12	36	13	12	13	48	14	24	15	0	15	36	16	12	16	48	17	24
30	18	0	18	36	19	12	19	48	20	24	21		21	36	22	12	22	48	23	24
40	24	0	24	36	25	12	25	48	26	24	27	0	27	36	28	12	28	48	29	24
50	30	0	30	36	31	12	31	48	32	24	33	0	33	36	34	12	34	48	35	24
60	36	0	36	36	37	12	37	48	38	24	39	0	39	36	40	12	40	48	41	24
70	42	0	42	36	43	12	43	48	44	24	45	0	45	36	46	12	46	48	47	24
80	48	0	48	36	49	12	49	48	50	24	51	0	51	36	52	12	52	48	53	24
90	54	0	54	36	55	12	55	48	56	24	57	0	57	36	58	12	58	48	59	24
For Millesimes	0	0	0	4	0		0	11	0	14	0	18	0	2	0	25	0	29	0	32

Example —See 8? Type of Cal 0 264 day Of this 26 = 15 gh 36 p and 004 = 14 palas So 0 264 day = 15 gh 50 p

APPENDIX I

Names of Nakshatras

1 Âshvini 2 Bharani 3 Krittikâ 4 Rôhini 5 Mriga 5 Ârdrâ 7 Punarvasu 8 Pushya 9 Âshleshâ, 10 Maghâ 11 Pûrvâ Phâlguni 12 Uttarâ Phalguni 13 Hasta 14 Chitrâ 15 Swâti 16 Vishâkhâ 17 Anurâdhâ 18 Jyesthâ 19 Mûla 20 Pûrvâṣhâdhâ 21 Uttrarâṣhâdhâ 22 Shravana 23 Dhanisthâ 24 Shatatârakâ 25 Pûrvâ Bhâdrapadâ 26 Uttarâ Bhâdrapadâ 27 Revati

Names of Yogas

1 Viskambha 2 Priti 3 Âyushamat 4 Saubhâgya 5 Shobhana 6 Atiganda 7 Sukarman 8 Dhriti 9 Shûla 10 Ganda 11 Vriddhi 12 Dhruva 13 Vyâghâta 14 Harshana 15 Vajra 16 Siddhi 17 Vyatipâta 18 Variyân 19 Parigha 20 Shiva 21 Siddha 22 Sâdhya 23 Shubha 24 Shukla 25 Brahmâ 26 Aindra 27 Vaidhriti

The Repeating Karanas

Their Numbers								Names
2	9	16	23	30	37	44	51	Bava
3	10	17	24	31	38	45	52	Bâlava
4	11	18	25	32	39	46	53	Kaulava
5	12	19	26	33	40	47	54	Taitila
6	13	20	27	34	41	48	55	Gara
7	14	21	28	35	42	49	56	Vanija
8	15	22	29	36	43	50	57	Bhadrâ

The Fixed Karanas

58 Shakuni 59 Nâga 60 Chatushpâda

1 Kinstughna

TABLE 39

Supplementary to Table 5

(*Based on the Sûrya-Siddhânta*).

Increase of Elements to be used in verification.

Tithi.	Vâra	Days.	☾'s anom.	☉'s anom.	Tithi.	Vâra	Days	☾'s anom.	☉'s anom.
			a	a				a	a
11	3·83	10·83	141·5	10·7	21	6·67	20·67	270·0	20·4
12	4·81	11·81	154·3	11·6	22	0·66	21·66	282·9	21·3
13	5·80	12·80	167·2	12·6	23	1·64	22·64	295·8	22·3
14	6·78	13·78	180·0	13·6	24	2·62	23·62	308·6	23·3
15	0·76	14·76	192·9	14·6	25	3·61	24·61	321·5	24·2
16	1·75	15·75	205·8	15·5	26	4·59	25·59	334·4	25·2
17	2·73	16·73	218·6	16·5	27	5·58	26·58	347·2	26·2
18	3·72	17·72	231·5	17·5	28	6·56	27·56	360·1	27·2
19	4·70	18·70	244·3	18·4	29	0·55	28·55	12·9	28·1
20	5·69	19·69	257·2	19·4	30	1·53	29·53	25·8	29·1

TABLE 40

For conversion of fractions of a Day into Ghatis and Palas

Centimes	0		1		2		3		4		5		6		7		8		9	
	g	p	g	p	g	p	g	p	g	p	g	p	g	p	g	p	g	p	g	p
·00	0	0	0	36	1	12	1	48	2	24	3	0	3	36	4	12	4	48	5	24
·10	6	0	6	36	7	12	7	48	8	24	9	0	9	36	10	12	10	48	11	24
·20	12	0	12	36	13	12	13	48	14	24	15	0	15	36	16	12	16	48	17	24
·30	18	0	18	36	19	12	19	48	20	24	21	0	21	36	22	12	22	48	23	24
·40	24	0	24	36	25	12	25	48	26	24	27	0	26	36	28	12	28	48	29	24
·50	30	0	30	36	31	12	31	48	32	24	33	0	33	36	34	12	34	48	35	24
·60	36	0	36	36	37	12	37	48	38	24	39	0	39	36	40	12	40	48	41	24
·70	42	0	42	36	43	12	43	48	44	24	45	0	45	36	46	12	46	48	47	24
·80	48	0	48	36	49	12	49	48	50	24	51	0	51	36	52	12	52	48	53	24
·90	54	0	54	36	55	12	55	48	56	24	57	0	57	36	58	12	58	48	59	24
For Millesimes	0	0	0	4	0	7	0	11	0	14	0	18	0	22	0	25	0	29	0	32

Example:—Sec. 82. Type of Cal; 0·264 day. Of this ·26 = 15 gh 36 p. and ·004 = 14 palas. So 0·264 day = 15 gh 50 p

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APPENDIX II

Note on the longitude of the star Spica

The following two verses, which are quoted from Garga Samhitâ by Somâkara the commentator of Vedânga Jyotisha clearly show the fact that the longitude of the star Spica was 180° in the ancient Hindu Zodiac. Its division into 27 equal parts called nakshatras, was made with respect to the star *a* Delphini which was used as a starting point in the matter of sidereal division

यदा माघस्य शुक्लस्य प्रतिपद्युत्तरायण ।

सहोदय श्रविष्ठाभि सोमार्को प्रतिपद्यत: ॥

तदाऽत्र नमस शुक्लसप्तम्या दक्षिणायन ।

सार्पार्धे कुरुते युक्ति चित्रया च निशाकरे ॥

By the use of the plural word श्रविष्ठाभि the author means the chief star of the cluster. The verses mean that when on the first day of माघशुक्ल the sun and the moon arrive together at the winter solsticial point marked by the star *a* Delphini, the next summer solstice takes place on the 7th day of the bright half of the month नभस् the sun being then at the middle point of the division सार्धे and the moon in conjunction with the star चित्रा (Spica)

This description undoubtedly means that the distance of the star Spica from the star Alpha Delphini is equal to the mean motion of the moon in six tropical months, that is in 182 days 37 ghatis and 16 palas. Now the best modern tables give for the moon's motion during this period 246° 17′ 2. Deducting from this the distance of *a* Delphini to the first point of Ashvini which is equal to $13° 20' \times 5 = 66° 40'$, we get 179° 37′ 2 for the longitude of Spica which in round number was said to be 180°

This result can also be arrived at independently in another way. The sidereal longitude of *a* Delphini is $13° 20' \times 22 = 293° 20'$. Deducting from this the distance from Spica to *a* Delphini, which is by my Jyotirganita p 232 113° 32′ 6, there remain 179° 47′ 4 for the longitude of Spica which is almost 180 degrees

The giving of names to the 27 divisions seems to have taken place about the year B C 2000, when the tropical longitude of the first point of the Ashvini division was 330°. The year of the Aryans and other ancient nations generally commenced when the sun's longitude was 330°. The Chinese still begin their year in that lunar month in which the sun arrives at the 330th the degree of tropical longitude.

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